MARKET FAILURE IN DISEASE CONTROL: BOVINE VIRAL DIARRHEA VIRUS (BVDv) AND THE ECONOMIC FEASIBILITY OF ENHANCED CONTROL IN THE BEEF CATTLE INDUSTRY

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Bachelor of Science in Agriculture Economics

New Mexico State University

Las Cruces, New Mexico

2016

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May 2018

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ACKNOWLEDGEMENTS

I would like to thank my family and friends who have helped me come this far and supported me through this chapter in my life.

"I can do all things through Him who gives me strength."

-Philippians 4:13

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Date of Degree: MAY, 2018

Title of Study: MARKET FAILURE IN DISEASE CONTROL:

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OF ENHANCED CONTROL IN THE BEEF CATTLE INDUSTRY

Major Field: AGRICULTURE ECONOMICS

Abstract: Bovine Viral Diarrhea Virus (BVDv) is a disease that has effects that are not identified by the majority of operations in the beef industry. This research is designed to evaluate the cost of the disease at every level and compare that to the cost of implementing an enhanced control system. By evaluating the cost of vaccination and eradication versus morbidity and mortality from cow-calf operations, feeder/backgrounding operations, and feedlot operations a base partial budgeting model can be used to determine the cost of BVDv on each individual operation and the cost of vaccination and eradication. A cost-benefit analysis on every level will determine if enhanced control is a cost-effective endeavor for the industry. This will indicate that feedlots and stockers would benefit from providing a monetary incentive to cow-calf producers to vaccinate and eradicate possibly infected animals would be plausible. This disease can be better managed if the industry implements a control program across all sectors.

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CHAPTER I

INTRODUCTION

Throughout history, there have been many diseases that have impacted the cattle industry. Over time, vaccines have been developed and certain diseases have been eradicated. For many years, the cattle industry has been affected by Bovine Viral Diarrhea virus (BVDv) on every level from the cow-calf operations to stocker/backgrounding and then on to feedlot operations. Estimations of the annual cost of BVDv to the cattle industry ranges from $500 million to $1.9 billion dollars (Miles, 2009) (Ishmael, 2013). Determining the economic impact of Bovine Viral Diarrhea in the beef industry and the economic feasibility of enhanced control at the cow-calf level is necessary to determine if controlling the disease is cost-effective to the beef industry. The economic impact caused by Bovine Viral Diarrhea is not fully recognized and is costing producers thousands of dollars which could be alleviated through enhanced control.

Problem Statement:

Bovine Viral Diarrhea Virus (BVDv) is a disease that affects every level of the beef industry. At the cow-calf level, pregnant cattle that are infected have abortions and premature births. Calves infected in the fetus, are born as Persistently Infected (PI) calves and a majority do not live to weaning. This reduces the number of calves sold which in turn reduces income. If the PI calves survive weaning, they are usually sold to a stocker/feedlot operation. Once cattle are at a stocker/feedlot operation, commingling occurs. The PI cattle then expose many other cattle that may be susceptible to the disease. This causes an increase in cattle sickness and death loss. PI cattle are often chronically ill and perform poorly in normal conditions where healthy cattle typically thrive. There is a high mortality rate throughout chronically PI cattle and every sector loses money from PI cattle.

This research will be using different categories of respiratory diseases. The terms are difficult to decipher and keep straight, therefore this is designed to help understand the differences in the terms. BVDv is the main focus of this research which examines how the implementation of an enhanced disease control program will impact the beef industry. BVDv-PI cattle are cattle that have BVDv as a chronic illness and shed the disease for the entirety of their lives, even when asymptomatic. BVDv acute infection occurs when a BVDv-PI animal infects another animal. BRD or Bovine Respiratory Disease is the disease that BVDv is closely associated with. Therefore literature and resources are closely related to each other and some assumptions are pulled from BRD research. BRD is a complex disease that BVDv is often incorporated with. This makes finding specific information only regarding BVDv difficult. Prevalence is the percentage of herds or operations that have a BVDv positive animal. Incidence is the percent of animals that are infected in those individual operations.

Estimated losses that are associated with BVDv have a wide range across multiple sources and databases. Estimated outbreaks of BVDv in a cow herd has a general cost estimate of $50-$100 per cow (USDA APHIS, 2007). Severe outbreaks that occurred in Canada in 1998 had estimated costs of $40,000-$100,000 per herd or $400 per cow (USDA APHIS, 2007). However, Bovine Respiratory Disease (BRD) is estimated to cost the cattle industry a total of $500 million per year (Miles, 2009). The total cost of BVDv was estimated at $1.9 billion annually in 2011 (Ishmael, 2013). Another source states that BVDv costa both the beef and dairy industry upwards of $3 billion each year (Animal Health, 2016). These evaluations include morbidity, mortality and production losses caused by the disease. The variation of these estimations are attributed to the different factors and costs associated with the disease.

In spite of the high costs associated with BVDv, BVDv-PI and BRD, increased control has not occurred. The costs are largely attributed to the stocker and feedlot levels, however, cow-calf operations are the critical stage in controlling the disease. This has created disconnect between the willingness to incur costs to control the disease and the benefits of the enhanced control between these sectors that are not distributed equally.

While industry-wide costs of BVDv have been assessed, the costs have not been determined for each individual sector. Evaluating BRD, BVDv, and BVDv-PI cattle will determine if the cost of vaccination and enhanced control is feasible. This research will help identify the economic impact caused by Bovine Viral Diarrhea virus and the cost of eradication versus the benefits of enhanced disease control for each sector and the incentives required to implement a control program.

Objectives:

The overall objective of this research is to determine the economic impact of BVDv within individual sectors of the beef cattle industry and the feasibility of control/eradication programs.

Specific objectives of this research were:

1. Determine the incidence and distribution of Bovine Viral Diarrhea virus in cow-calf, stocker and feedlot sectors.
2. Determine the use and efficacy of emerging diagnostic and control technology (testing, vaccines, eradication) for BVDv.
3. Determine the costs borne by each sector resulting from the disease compared to the benefit of enhanced control in each sector.
4. Identify changes in incentives needed at each sector to improve/increase control efforts.

CHAPTER II

REVIEW OF LITERATURE

BVDv can vary greatly in its presentation in cattle from cow-calf operations to stocker to feedlot operations, with detrimental impacts every level (Kerr, Hopkins, and Welborn, 2001). Symptoms range from fever, depression, diarrhea, respiratory disease, runny nose/eyes and can end in either a full recovery or death. Whether cattle survive is dependent on several factors; including: immune status of the animal, the strain of infection, and age of the animal (Stokka, et. al 2000). Determining what this disease is costing the beef industry as a whole is necessary to determine the economic impact of Bovine Viral Diarrhea on the beef industry.

BVDv (The Disease)

Bovine Viral Diarrhea Virus or BVDv is a respiratory disease that affects the immune systems of cattle. BVDv is one of several disease organisms that make up the Bovine Respiratory Disease (BRD) complex (See page 10). The term BVDv refers to a heterogeneous group of viruses that belong to two different species, BVDv1 and BVDv2, within the *pestivirus* genus of the Flavivirus family. BVDv has two sub biotypes, cytopathic (CP) and noncytopathic (NCP). Distinction is based on the characteristics of the virus when grown in a laboratory in tissue culture. The strain of BVDv1a is considered the NCP strain. This strain reproduces without damage to infected cells and represents about 95 percent of the field isolates, meaning the calf has a possibility of survival even though it is infected. The CP type results in the death of target cells and death of the animal which represents the remaining 5 percent of the field isolates. These antigenic variations of the viral surface proteins are the result of the two BVDv types, type 1 and type 2 (Ridpath, 2010 'B'). Fetal infection can lead to early embryonic death, abortion, congenital defects, the birth of Persistently Infected (PI) calves, or the birth of normal calves. The immune status of the dam, the stage of gestation at the time of infection, and the viral biotype are important factors in determining the result of vertical infection (Larson, 2015). The majority of BVDv infections are subclinical, with the severity of disease determined by the type of strain and the hosts' susceptibility. However, BVDv infections almost always produce some degree of immunosuppression determined by the virus of the infecting strain. If the animal is exposed to other pathogens while it is immunosuppressed, morbidity and death-loss will most likely be greatly increased. Initial infection is in the respiratory or vaginal mucosa, followed by systemic viral replication and widespread infection of the immune, respiratory, reproductive, and enteric systems (Wittum, et. al. 2001). Infected cattle shed BVDv in various body fluids and tissues including saliva, nasal discharge, blood, feces, urine, and aborted fetal tissues throughout their infection. Persistently infected animals can shed more viruses and for their entire lives while acutely infected cattle only shed while they are contagious (Larson, 2015).

The incidence and infection rate of BVDv-PI cattle throughout the United States is relatively low. With approximately 4 percent of herds across the United States having at least 1 or more PI animals in their herds and the incidence rate within the herd being approximately 0.3 percent, the disease's severity is underestimated (Mason, et. al. 2005). From the 2012 Census of Agriculture report, the total number of beef farms that contained cows and heifers that calved was 727,906 (USDA NASS, 2012). BVDv is transmitted within a herd or during comingling in two different ways. The first way to pass the disease from one animal to another is through bodily fluids when an animal is infected and sheds the virus (horizontal). The second method is when a dam infects the fetus during pregnancy (vertical). Horizontal transmission or acute infection of BVDv results in a temporary (transient) infection or acute infection that is usually mild but can result in severe disease. Vertical transmission results in either death or PI animals that carry and shed the disease for the entirety of their lives (Larson et. al., 2005). Historically, virus isolation in cultured bovine cells has been the standard against which other tests were evaluated. Vaccination is effective in reducing the spread of BVDv but cannot on its own eliminate BVDv from populations (Ridpath, 2010 'A'). Direct contact with animals is the most common form of transmission since the virus does not survive an extended period in the environment. Infection during the breeding season could result in abortion or infertility. Infection during the first half of gestation could result in abortions or the birth of persistently infected calves. Infection during the second half of gestation could result in abortions, birth defects, stillbirths or weak calves (Strickland, 2017). Although abortions and weak calves have been attributed to BVDv infection in late gestation, infections occurring earlier in gestation generally have a greater impact on reproduction (Ridpath, 2010 'B'). Diagnosis may be made on clinical signs that are typical of the viral respiratory disease, including fever, depression, loss of appetite, and ocular and nasal discharge, followed by diarrhea several days after onset. Sores or ulceration in the mouth and gums may be present, along with reduced milk production in cows. Virus isolation from blood, milk, and tissues is useful in diagnosing BVDv (Stokka, et. al 2000). Persistently infected animals (PIs) may appear normal or may suffer from an array of congenital anomalies, including defects of the nervous system, eyes, skeletal system, and skin/hair. BVDv is implicated as a cause of infertility, abortions, diarrhea, shipping fever, immunosuppression and more.

Persistently Infected Animals

The principal reservoir of BVDv is Persistently Infected (PI) animals. PI cattle are more likely than normal cattle to require treatment for respiratory tract disease and can become chronically ill or die (Ridpath, 2010 'A'). The PI animal also has a high risk of succumbing to a highly fatal form of BVDv called mucosal disease (BVDv-MD). BVDv-MD is the sequela of a persistent infection with non-cytopathic BVDv strain, followed by an acute concurrent infection with a cytopathic BVDv strain. The clinical presentation of the reproductive disease is due to the direct infection of the fetus and the outcome depends on the stage of gestation in which the fetal infection occurs. Exposure to bovine viral diarrhea viruses (BVDv) results in acute and persistent infections. Persistent Infections result from in utero exposure during the first trimester of gestation. The clinical presentation in persistently infected cattle (PI) is highly variable. The reasons for this variation is largely unknown. The BVDv circulating in PI exist as quasi-species (swarms of individual viruses). In one study, an outbreak that resulted in 34 PI cattle presented an opportunity to compare a large number of PI's in a herd environment. Scientific methods were developed to compare the circulating viral populations within PI animals. The results found that PI animals generated in the same outbreak were carrying circulating viral populations that differ widely in size and diversity. Further, it was demonstrated that variation in PI viral populations could be used as a quantifiable phenotype. This observation makes it possible to test the correlation of this phenotype to other phenotypes such as growth rate, congenital defects, viral shed and cytokine expression (Ridpath, et al. 2015).

The objective of another study was to estimate the prevalence of cattle persistently infected (PI) with bovine viral diarrhea virus (BVDv) at arrival at a feedlot, prevalence of chronically ill and dead PI cattle, and the magnitude of excess disease attributable to a PI animal (Larson, 2015). Most feedlot cattle in the United States are administered a BVDv containing vaccine upon arrival of a feedlot. However, well-controlled vaccine efficacy studies conducted in real-world settings are generally lacking. This study included cross-sectional and cohort studies. The study included 2,000 cattle and at the time that they arrived at the feedlot, there were 1,383 chronically ill cattle from 7 feedlots, and 1,585 dead cattle from a single feedlot. The procedure that was used to conduct the study included sample collection and processing. Skin biopsy specimens were collected and evaluated via immunohistochemistry. Cattle were characterized as either PI or non-PI with BVDv on the basis of characteristic immunostaining. Follow-up testing was obtained for the 2,000 cattle sampled at arrival, and health outcomes were determined for cattle exposed and not exposed to a PI animal. The results indicated that the prevalence of PI cattle was 0.3 percent at arrival, 2.6 percent in chronically ill cattle, and 2.5 percent in dead cattle. Risk of initial treatment for respiratory tract disease was 43 percent greater in cattle exposed to a PI animal, compared with those not exposed to a PI animal. Overall, 15.9 percent of initial respiratory tract disease events were attributable to exposure to a PI animal. In conclusion, relatively few PI cattle arrive at feedlots. However, those cattle are more likely to require treatment for respiratory tract disease and either become chronically ill or die than cattle that are not PI. In addition, they are associated with an increase in the incidence of respiratory tract disease of in-contact cattle (Mason, et. al. 2005).

The determination of the total impact of persistently infected animals must factor in the contribution of acute, uncomplicated BVDv infections. The impact of the respiratory disease in animals persistently infected with BVDv results in the immunosuppression that accompanies acute BVDv infections and this leads to animals being susceptible to secondary infections (Ridpath 2010 ‘B’). Feedlots and stocker operations are at a higher risk due to the increased amount of commingling that occurs within the feedlots as well and through auctions and transportation before the cattle arrive at their operations.

Bovine Respiratory Disease

Typically, BVDv is grouped with Bovine Respiratory Disease (BRD) because the diseases are similar, and most current literature focuses heavily on BRD. BRD accounts for approximately 70 percent of feedlot morbidity and 50 percent of feedlot mortality, negatively affecting profit. United States Department of Agriculture (USDA) National Animal Health Monitoring System (NAHMS) Beef Feedlot 2011 Study (USDA, 2013) reports that the direct cost of treatment of respiratory disease in feedlot cattle is USD $23.60 per case. The total cost of treating 2.29 million cattle for respiratory disease is, therefore, estimated to be USD $54.12 million, not including production losses due to morbidity and mortality. Reducing BRD prevalence would result in increased supplies of beef cattle through lower morbidity and mortality rates (Johnson and Pendell, 2017).

The North American beef cattle industry has endured many changes throughout the years but is encountering some of the most dramatic challenges in history during the first decade of the 21st century. The US beef cattle inventory increased from 1990 to a high of 103.5 million in 1996 and since has declined to a low of 94.5 million on 1 January 2009. Even though economic signals have encouraged the cow herd to increase over the last 5 years, a significant decrease occurred during 2008. It is difficult to determine the precise cost of bovine respiratory disease (BRD) to the industry but it is reported to be greater than US$500 million per year.

"Data from our practice indicate that losses from BRD over the last 18 years have been characterized by 5-year cycles of decreases and increases. Perhaps it is time for the industry to look for ways to reduce death loss by methods that focus on the animal's response to the pathogens instead of continuing to focus on the pathogens" (Miles, 2009).

BVDv has multiple symptoms that are attributed not only to BVDv but also to respiratory infections such as BRD, with signs similar to Infectious Bovine Rhinotracheitis (IBR), plus oral and tracheal ulceration Thrombocytopenic (bleeder) syndrome, where type 2 BVDv infects blood cells and bone marrow, causing destruction of red blood cells, reduced clotting function, bleeding from wounds, lesions, and internal organs as well as reproductive diseases resulting in embryonic loss and abortions. Persistent infection (PI), which results when a calf is infected in utero with NCP BVDv during the first trimester of gestation and survives, and results in a continuing reservoir of BVDv infection. Animals with PI are often outwardly normal. Mucosal disease occurs when an animal with PI is exposed to a CP strain of BVDv, resulting in explosive diarrhea and ulceration throughout the digestive tract and in most cases, death. When cattle are immunosuppressed with BVDv, they are 68 percent more likely to suffer from additional diseases attributed to BRD (Fulton et. al., 2006).

Many predisposing factors have been implicated in reducing the death-loss impact including stress from weaning, transportation, mixing of cattle, handling, and processing. Viruses, including parainfluenza-3, bovine respiratory syncytial virus, bovine herpes virus-1, coronavirus, and BVDv. All of these issues have been implicated as predisposing causes of BRD (Brooks, et. al. 2011). Respiratory infection with BVDv is characterized by signs typical of the viral respiratory disease, including fever, depression, lack of appetite, and eye and nasal discharge, sores or ulceration in the mouth and gums may be present, along with reduced milk production in cows (Stokka, et. al 2000). Typically, once an animal is infected or susceptible to BVDv then the immune system is compromised and a variant on its ability to fight off additional infections which leaves extensive room for BRD to manifest.

The cost of eradicating and vaccinating for the disease is a huge issue that the cattle industry is attempting to address (Vestal, Richeson, 2014). BRD can cause significant economic losses for cattle producers. On average, producers lost approximately $122 per head (Brooks, et. al. 2011). However, by testing three different herd levels versus three different levels of prevalence, it was determined that testing for BVDv is not necessarily economically efficient. Testing a whole herd for BVDv is a significant cost to producers. When a herd is infected with PI cattle, it is slightly beneficial cost wise to test for BVDv. Since this study was conducted, there have been many advances in the testing industry that is making the testing strategies cost less and less, however, it is still considered to be a loss to producers to test. This may not always be the case in the future with more advanced technology. When there are no PI cattle, then testing is considered a negative value for producers. Overall, this study revealed that implementing whole herd testing strategies for BVDv is rarely a beneficial economic endeavor (Nickell, et. al. 2011). The likelihood of PI cattle being in herds is at a low enough percentage that farmers would not typically assume the cost to screen for BVDv (Larson, et. al. 2002).

Cow-Calf Impacts

The impact that BVDv can have on a beef herd is tremendous and often goes undetected. Even mild or subclinical infections of susceptible breeding females can cause conception failure, early embryonic loss, abortion, or vertical fetal infection. Most BVDv infections occur in the first trimester of gestation leading to calves that are in turn persistently infected (Larson, 2015). Persistently infected cows always give birth to PI calves and are much more likely to infect other cows who will, in turn, give birth to PI calves (Stokka, et. al. 2000). The presence of multiple PI calves in a herd suggests the presence of multiple susceptible females in the herd as well as possible PI cows. Herds with PI calves had a 3 percent lower pregnancy rate than non-PI infected cattle. Persistently infected calves that survive to weaning provide a constant source of the disease to the rest of the herd and could result in more PI calves born every year without proper intervention (Wittum, et. al. 2001).

Another study determined the prevalence of bovine viral diarrhea virus (BVDv) in persistently infected (PI) cattle in beef breeding herds using 30 herds with 4530 calves (Grooms et. al. 2001). The samples were collected by ear notches and tested for BVDv antigens using immunohistochemistry (IHC) and antigen capture enzyme-linked immunosorbent assay (ACE). This was the most effective way to test for BVDv-PI animals in a herd environment.

Current marketing of cattle and delivery of cattle to the feedlot represents a major potential for PI cattle to enter a feedlot. For example, a recent study demonstrated that of 21,743 cattle entering a feedlot, 0.4 percent were PI (Fulton, et al. 2009). These cattle were purchased by order buyers from 10 southern and southeastern states and were delivered into 240 separate pens, 74 (30.8 percent) of these pens had a PI animal. Thus, the goals for cattle entering the feedlot should be high and effective immunity to BVDv, but it is also important for the cattle to be free of exposure to PI cattle (Fulton, et al. 2009). Detecting and eliminating persistently infected cattle is used as a method to control BVDv in infected herds and prevent the introduction of BVDv into non-infected herds.

Persistent infection develops after in-utero exposure to BVDv that result in immunotolerance. Therefore, among the 1,952 cattle tested in the study, BVDv was detected in 5 cows (0.26 percent) from the 3 of the 13 farms (Grooms et. al. 2001). In each of the 5 cows, the virus was detected in serum and white blood cell count (WBC) preparations. BVDv was again isolated from serum and WBC preparations from each of the 5 cows, indicating that these cattle were persistently infected with the virus. No cows were found in which BVDv could only be isolated from WBC and not serum (Grooms, et. al. 2001).

Stocker and Feedlot Impacts

An even larger impact than impact on cow-calf operations is inflicted on stocker and feedlot operations. The US Department of Agriculture estimates 10.7 million cattle were placed on feed in the United States in 2016 and 2.0 percent of cattle (214,000 head) placed on feed either died or were sent to market before reaching desired slaughter weight (Ridpath, 2010 ‘A’). In addition to the direct losses of BVDv-PI cattle, feedlots may experience losses among non-PI cattle that are transiently infected with BVDv due to virus transmission from PI cattle. Transmission of BVDv from PI cattle to in-contact susceptible cattle occurs during marketing, trucking, and while in feeding pens and pastures. Vaccination against BVDv antigens at the time cattle arrive at a feedlot as well as earlier in the cattle production system is a common intervention to reduce the biologic and economic costs of BVDv in feedlot cattle. A small percentage of cattle are BVDv-PI with and constitute the primary reservoir for the virus; however, they shed the virus and can cause immunosuppression in up to 79 percent of a herd or operation. Testing and removal of PI cattle at feedlot arrival or earlier can effectively remove nearly all the BVDv reservoir from the population even if the test returns a few false-negative results (Larson 2015).

The economic cost of BVDv-PI cattle at feedlot arrival will depend on the prevalence of PI cattle (Larson, 2015). If BVDv makes it into feed yards, the disease can cost $31-$41 per head. That amounts to costing the industry about $3 billion each year. BVDv testing costs $2.50 - $3.50 per head depending on the number of samples tested and the size of the pools. According to Superior Livestock Auctions, buyers paid about $2.42 more per hundredweight for BVDv-PI tested calves at auction. This is approximately $10 per head net profit for tested cattle. In one example: a 10,000-head feedlot was tested. There was only about 0.4 percent prevalence but 72 percent of the pens were exposed to the disease. The observed cost of the disease per animal was $47.92, resulting in a cost to the feedlot of $479,200 compared to testing costs of $35,000 (Animal Health, 2016). BVDv is most often found in cattle younger than 2 years of age and affects multiple body systems of the animal decreasing the immune system's ability to fight infections. As a result, feedlot and stocker producers face relatively higher production costs with the presence of BVDv due to poor feed conversion and higher mortality since 90 percent of their cattle are under 2 years of age. Because the prevalence of BVDv can vary, it is estimated that exposing a general population of feedlot cattle to PI animals' costs $67.49 per head due to performance losses and fatality (Williams, Corbin, Blue, 2013). Testing and control of PI-BVDv continue to be a challenge for the cattle industry. As stocker and feedlot producers continue to face tighter profit margins, the cost of testing for BVDv does not seem feasible or necessary (Vestal, Richeson 2014). This is why the economic cost of PI cattle in feedlot operations, and the value of removal of PI cattle after test results should be determined (Larson, 2015). Ultimately, control of this pathogen will rest with the cow-calf industry. The use of pre-breeding vaccines with modified live vaccines that can demonstrate fetal protection will be the most significant tool currently available to eliminate the presence of PI calves. Enhanced BVDv biosecurity programs that effectively identify and remove PI cattle from herds and prevent their introduction will be critical to controlling the disease at all levels of the industry. The widespread availability of immunohistochemical tests for BVDv will provide a sensitive means for which producers to accomplish this goal. Voluntary BVDv eradication programs and herd certification programs could give feedlot operators a source of calves that will be at a lower risk for containing PI calves. In combination with pre-vaccination programs, these types of efforts may provide an opportunity to decrease the role that BVDv plays in infectious disease of feedlot cattle (Campbell, 2004).

In one study, 7,544 stocker calves purchased from an order buyer from auction markets in Alabama, Florida, Georgia, Mississippi, and Tennessee were sampled from March to December 2005 (Stephenson, et al. 2017). Following the purchase, calves were transported to a central holding facility where the calves were processed, sorted, and assembled into 28 truckload lots based on average body weight. Skin biopsies (ear notches) were collected in zinc-buffered formalin for the detection of BVDv persistent infection using immunohistochemistry. Twenty-four BVDv-positive calves were detected in a sampling of 7,544 calves. The overall BVDv PI prevalence in stocker calves sampled was measured at 0.318 percent. Therefore, with 95 percent confidence, the BVDv-PI prevalence was between 0.19 percent and 0.45 percent. This prevalence aligned closely with the BVDv PI prevalence rates that have been reported previously in other regions of the United States (Stephenson, et al. 2017). In this study, calves weighing less than 180 kg had greater BVDv PI prevalence with 2.78 times greater probability of being PI animals compared with calves over 180 kg. Interestingly, Southeastern United States cattle are widely considered to be at a high risk of disease by feedlot managers. This might be associated with stress induced by long-distance travel impairment of immune responsiveness, a low percentage (59.8 percent) of operations using vaccines, or presence of PI animals, resulting in high morbidity of shipped stocker cattle. Moreover, it is well documented that BVDv PI calves have lighter BW than BVDv-negative calves of the same age. Therefore, purchasing light body weight cattle might represent a risk for acquisition of PI stocker cattle.

Fulton, et al (2006) indicated that the prevalence of cattle PI with BVDv entering a feedlot was also 0.3 percent. BVDv-PI cattle are important sources of virus and shed large quantities of virus, thus exposing other cattle in direct or close contact, including pen-mates or those in adjacent pens or transportation units. Risk of initial treatment for BRD was 43 percent in cattle exposed to a PI calf. In that study, 0.3 percent of cattle entering a feedlot were PI animals, 2.6 percent of chronically ill cattle were PI, and 2.5 percent of cattle that died were PI. The authors of that study reported that 15.9 percent of initial cases of BRD were attributed to exposure to PI calves. Although the prevalence of PI cattle entering a feedlot is low, considerable disease may develop in exposed cattle. Thus, control of feedlot diseases appears to be aided by removal of PI calves, minimizing risks attributable to those calves. The 86 PI calves were held in quarantine pens or subsequently remained in the starter yard. Within approximately 60 days after processing and arrival, 22 of the 86 PI calves had died; 14 had the mucosal disease, 6 had respiratory tract disease, 1 had bloat, and the diagnosis in 1 calf was not known (Fulton, et. al. 2006).

Furthermore, another study researched cattle that were housed in 20 pens of approximately 100 cattle each and managed in accordance with routine feedlot practices. During initial processing, cattle were evaluated for signs of illness by trained feedlot personnel. When cattle suspected of being ill were identified, they were moved to a cattle-handling facility and treated according to treatment protocols developed by the consulting veterinarian. Cattle were typically deemed to be chronically ill if they failed to respond favorably to the administration of 3 courses of treatment. These cattle were removed from group 1 and transferred to a separate feedlot for convalescent cattle. Cattle that died underwent postmortem evaluation, and cause of death was assigned under the supervision of the consulting veterinarian. In the first analysis, which evaluated the effect of exposure to a PI animal on morbidity rate, exposure was defined as those cattle within a pen that contained a PI animal. Overall, cattle in 4 pens that contained 402 cattle were considered exposed, whereas cattle in 16 pens that contained 1,598 cattle were considered not exposed. The risk of disease in exposed and not exposed cattle was 7.0 percent and 5.9 percent, respectively; these were not significantly different (relative risk, 1.17; 95 percent CI, 0.74 to 1.69 [$P = 0.60$]). The incidence of disease in the exposed and not exposed cohorts was 4.6 and 3.9 treatments 10,000 head-days, respectively (rate ratio, 1.18; 95 percent CI, 0.75 to 1.76 [$P = 0.53$]). Pens with exposed cattle were more likely to have cattle with greater than mean risk of treatment for respiratory tract disease ($P = 0.03$); cattle in 7 of the 10 pens with cattle with the greatest risk of treatment were exposed to a PI animal, whereas cattle in only 2 of the 10 pens with cattle with the lowest risk for treatment were exposed. When incidence rates were compared between cohorts, exposed cattle had 48 percent greater ($P = 0.03$) incidence of initial respiratory tract disease, compared with non-exposed cattle (Longeragan, et al. 2005).

Vaccination and Control

Based on the NAHMS 2007-08 Beef Cow-calf study, only 12.3 percent of cow-calf operations were unfamiliar with BVDv and 64.0 percent of operations knew some basics or were fairly knowledgeable about the virus. These results are likely a reflection of the substantial coverage the agriculture media has devoted to BVDv in the past few years. While producers are generally aware of BVDv, relatively few (4.2 percent) had done any testing of calves for persistent infection with the virus in the past 3 years. Larger operations (200 or more beef cows) were much more likely than smaller operations to have tested calves for persistent infection with BVDv in the past 3 years (15.6 percent of operations). The low overall rate of testing might indicate that most producers do not believe their herd is at risk. Producers might also believe that the cost-benefit ratio for controlling the disease is prohibitive. Among the 44,150 ear-notch samples collected and tested, only 53 (0.12 percent) were positive for the BVDv antigen (USDA, 2010).

The most commonly used tests are the immunohistochemistry test (IHC) done on ear notches preserved with formaldehyde and the antigen capture ELISA test (ACE) done on fresh ear notches or blood serum. The Kord Animal Disease Diagnostic Lab in Nashville performs the ACE test. Recent research has shown this test to be as useful and accurate as the IHC test. The test has a quick turnaround time but in certain cases, it should be repeated in 3 weeks to distinguish between PI calves and newly infected calves. A good vaccination program that will be successful against BVDv should begin at about 6 months of age of the calf. Many good BVDv vaccines are available and if used properly can be expected to be a very useful part of BVDv control in the cowherd. Vaccination along with biosecurity measures are needed to keep the disease out of the herd and the beef industry as a whole. These measures would include maintaining a closed herd or buying only from known BVDv free herds. Testing should also occur when any new animals are brought into the location and should be isolated from the rest of herd for 1 month after arrival as a precaution (Kerr, Hopkins, and Welborn, 2001).

One study compared the effectiveness of reproductive protection in cattle against bovine viral diarrhea virus (BVDv) and bovine herpesvirus 1 (BoHV-1) through the annual revaccination with multivalent modified-live viral (MLV) vaccine or multivalent combination viral (CV) vaccines (Houe, Lindberg, Moennig, 2016). These vaccines contained temperature-sensitive modified-live BoHV-1 and killed BVDv and were given pre-breeding to nulliparous (not pregnant/have not had a calf) heifers. Seventy-five beef heifers were allocated into treatment groups A (n = 30; two MLV doses pre-breeding, annual revaccination with MLV vaccine), B (n = 30; two MLV doses pre-breeding, annual revaccination with CV vaccine) and C (n = 15; saline in lieu of vaccine). Heifers were administered treatments on days 0 (weaning), 183 (pre-breeding), 366 (first gestation), and 738 (second gestation). After first calving, primiparous (only having one calf thus far) cows were bred, with pregnancy assessment on day 715. At that time, 24 group A heifers (23 pregnancies), 23 group B heifers (22 pregnancies), and 15 group C heifers (15 pregnancies) were commingled with six persistently infected (PI) cattle for 16 days. Ninety-nine days after PI removal, cows were intravenously inoculated with BoHV-1. All fetuses and live offspring were assessed for BVDv and BoHV-1. Abortions occurred in 3/23 group A cows, 1/22 group B cows, and 11/15 group C cows. Fetal infection with BVDv or BoHV-1 occurred in 4/23 group A offspring, 0/22 group B offspring, and 15/15 group C offspring. This research demonstrates the efficacy of administering two pre-breeding doses of MLV vaccine with annual revaccination using CV vaccine to prevent fetal loss due to exposure to BVDv and BoHV-1 (Walz, et. al. 2017).

Several European countries have initiated national and regional control and eradication campaigns for bovine viral diarrhea virus (BVDv). In European countries without organized BVDv control programs, vaccination is still commonly used to control BVDv. Diagnostic test strategies are fundamental to all control and eradication campaigns and how the utilization of available diagnostic tests are used to maximize efficacy. Laboratory techniques are available for BVDv diagnosis at the individual animal level and at the herd level. These are strategically used to achieve 3 main objectives: 1) initial tests to classify herd status, 2) follow-up tests to identify individual BVDv-infected animals in infected herds, and 3) continued monitoring to confirm BVDv free status. For each objective or phase, the validity of the diagnostic tests depends on the mode of BVDv introduction and duration of infection in test-positive herds, and on how long non-infected herds have been clear of BVDv (Houe, Lindberg, Moennig, 2016).

Wittum, et al. (2001) collaborated with 48 different veterinary practices to use as a sampling cluster and select herds that were required to have 20-500 head of cattle from each frame in the list. This study tested the prevalence of BVDv in beef herds by using a sampling throughout different veterinary practices and determining the effect that PI calves had on the herd as a whole. Blood samples were taken from the calves before they were 4 months old in each herd and sent to Ohio State University for testing. A second sample was taken at 6 months of age from the calves that tested positive for BVDv and were reexamined for the type of BVDv that was detected. The dams of the infected calves also had samples taken from them to determine the type and method of infection. The models that were used were based on production measures. The proportion of mature cows pregnant, the proportion of replacement heifers pregnant, the proportion of females that calved, the proportion of females that calved early in the season, neonatal mortality and postnatal mortality were the measures of production that were calculated. The production measures were compared to the herds and number of calves that tested positive for BVDv. The results showed that there were 56 BVDv positive calves out of 76 in suspected selected herds. At least one herd in every one of the five states was found to be BVDv positive. 10 out of 13 herds of randomly selected had cattle that tested positive. A second serum was obtained at 6 months of age from 43 of the 56 calves that initially tested positive and 33 of the initially infected animals then tested positive again so, therefore, they are PI calves. The other 10 of the 13 that a second sample was not obtained from were reported to be dead before 6 months of age. The samples taken from the dam of the 45 initially positive calves revealed that three dams on two farms were BVDv positive and were considered PI animals. The study confirmed that 3 percent of randomly selected herds had calves that were infected with BVDv. Moreover, 19 percent of suspected herds had calves that were infected with BVDv. The presence of multiple PI calves in a herd suggests the presence of multiple susceptible females in the herd as well. Herds with PI calves had a 5 percent lower pregnancy rate than non-PI infected cattle. Persistently infected calves that survive to weaning provide a constant source of the disease to the rest of the herd and could result in more PI calves born every year without proper intervention (Wittum, et. al, 2001)

Due to high capital requirements, disease prevention is more important than ever. The first commercial laboratory to offer BVDv-PI testing is Central States Testing. Central States Testing (CST) tests about 540,000 head annually. 90 percent of the cattle tested are at a high risk of susceptibility because they are from stockers and feedlots where the highest percentage of comingling occurs which manifests the disease. The prevalence rate based on the testing of the cattle is stagnant at 0.38-0.42 percent every year. The total cost of BVDv is estimated at $1.9 billion annually in 2011 (Ishmael, 2013). This is based on a cost of $35-$56 per head. Relatively few cattle arrive at feedlots that are PI infected cattle. However, BVDv is a catalyst for the common pathogens we deal with because of the immunosuppressive effect of the virus. The prevalence of PI infected cattle in this study was 0.3 percent. There is a detrimental impact on cattle that are exposed to PI-BVDv cattle due to the immunosuppression that causes multiple other diseases to occur. Economically, there is a loss of $93.52 per animal in this case study. The largest segment of the loss was in overall performance which amounted to $88.26 per animal while the remaining $5.26 per animal was a result of the increase in fatality percentage. The feed efficiency of feed conversion is the main factor that is impacted by BVDv. Unexposed cattle typically convert 55 percent more efficiently than cattle with direct exposure to BVDv. Heifers tend to be the most susceptible to birthing PI calves because of their lack of maturity and lower level of basal protection then mature cows.

Screening cattle for PI with BVDv prior to introduction to a herd can be accomplished through testing of individual skin biopsy specimens by means of IHC staining or through testing of pooled blood or serum samples with an RT-PCR assay. The use of pooled samples minimizes the expense of screening cattle from herds with a low prevalence of PI, in that all cattle represented in pooled samples for which assay results are negative are themselves considered to be negative for BVDv infection. However, pooled samples for which results are positive come from a mixture of cattle with PI, transiently infected cattle, and uninfected cattle, and confirmatory tests, such as IHC staining, must be performed on all animals represented in the pooled sample to identify animals with PI (Larson, et. al. 2005).

A simulation model for determining the economically optimum sample size in populations with a various prevalence of PI has been developed. As prevalence decreases, the least-cost initial pool size increases. The purpose of this study was to develop partial budgets to compare the economic costs of 2 test strategies for screening cattle for PI with BVDv. The test strategies that were evaluated included a single-test strategy, which consisted of IHC staining of skin biopsy specimens from all animals, and a 2-test strategy, which consisted of RT-PCR of pooled blood samples followed by IHC staining of skin biopsy specimens from animals in pools for which results were positive. The prevalence of PI with BVDv in feeder cattle was varied from 0.1 percent to 1.1 percent in intervals of 0.2 percentage points, the cost of a single IHC test was varied from $6 to $16 in $2 increments, and the cost of RT-PCR assaying of a single pooled blood sample was varied from $1.50 to $3.50 in $1 increments. The profit per calf and cost of feeder calves were fixed at $25 and $600, respectively. The cost of whole-herd diagnostic testing of feeder cattle for PI with BVDv was considered to be the sum of the costs associated with true-negative, false-positive, and false negative test results. The cost of true-negative test results was the cost of testing each calf negative for PI with BVDV and was calculated with the following formula: cost of true-negative test results = (1 – prevalence) X test specificity X test cost.

Because the most likely response to a positive test result is immediate euthanasia, the cost of false-positive test results was calculated from the cost of testing, the purchase price of the animal, and the forfeited profit of the animal with the following formula: cost of false-positive test results = (1 – prevalence) X (1 – test specificity) X (animal cost + test cost + forfeited profit). The cost of false-negative test results is largely the cost of the disease and was calculated with the following formula: the cost of false-negative test results = (prevalence X [1 – test sensitivity]) X (cost of PI with BVDv per animal + test cost). To justify a testing strategy, the cost of true-positive test results must exceed the combined cost of true-negative, false positive, and false negative test results. The cost of true-positive test results is largely influenced by the negative cost of feeder calves with PI for a feedlot or stocker operation and was calculated with the following formula: cost of true-positive test results = (prevalence X test sensitivity) X (cost of PI with BVDV per animal – test cost). In the present study, we found that if the prevalence of disease was low, the cost of PI with BVDV would need to be quite high when using the single-test strategy, even if the testing cost (ie, costs associated with animal handling, sample collection and submission, and laboratory testing and interpretation) was low ($6/test). As prevalence increased, the economic cost of PI with BVDv was necessary to justify this testing strategy decreased because the costs of screening were spread over more true-positive cattle (Larson, et. al. 2005).

Summary

BVDv is a contagious disease that can cost producers thousands of dollars. This disease is not always identifiable, is contagious and detrimental to herds that are susceptible. The cost of whole herd screening is not economically feasible for producers because the likelihood of being infected seems to be small enough that producers are not willing to assume the cost of testing. However, testing and controlling the disease has merit and should be considered to bridge the gap of market failure that this disease causes in the industry.

CHAPTER III

BVDv IN THE BEEF INDUSTRY

The beef industry is very complex for a variety of reasons (Peel, 2018 'A'). The industry consists of multiple production subsections including geographically dispersed cow-calf production; more concentrated stocker operations and highly concentrated feedlot finishing operations. These subsectors are connected by extensive animal transportation and commingling activities. One unique aspect of the industry is how cattle are moved and handled from weaning to the feedlots. There is not a direct path that every animal goes down which makes tracking and evaluating the movements of a single animal difficult. Each individual animal comes into contact with hundreds or thousands of other animals throughout their lifespan. BVDv is a unique challenge because PI cattle provide a continuous source reservoir of disease exposure. When incorporating a disease that is shed through individual contact, that amplifies the ability to spread the disease. Figure 1.0 provides a schematic example of how the virus starts at the cow-calf level and transfers all the way through to a feedlot operation and all of the different outcomes of the disease.

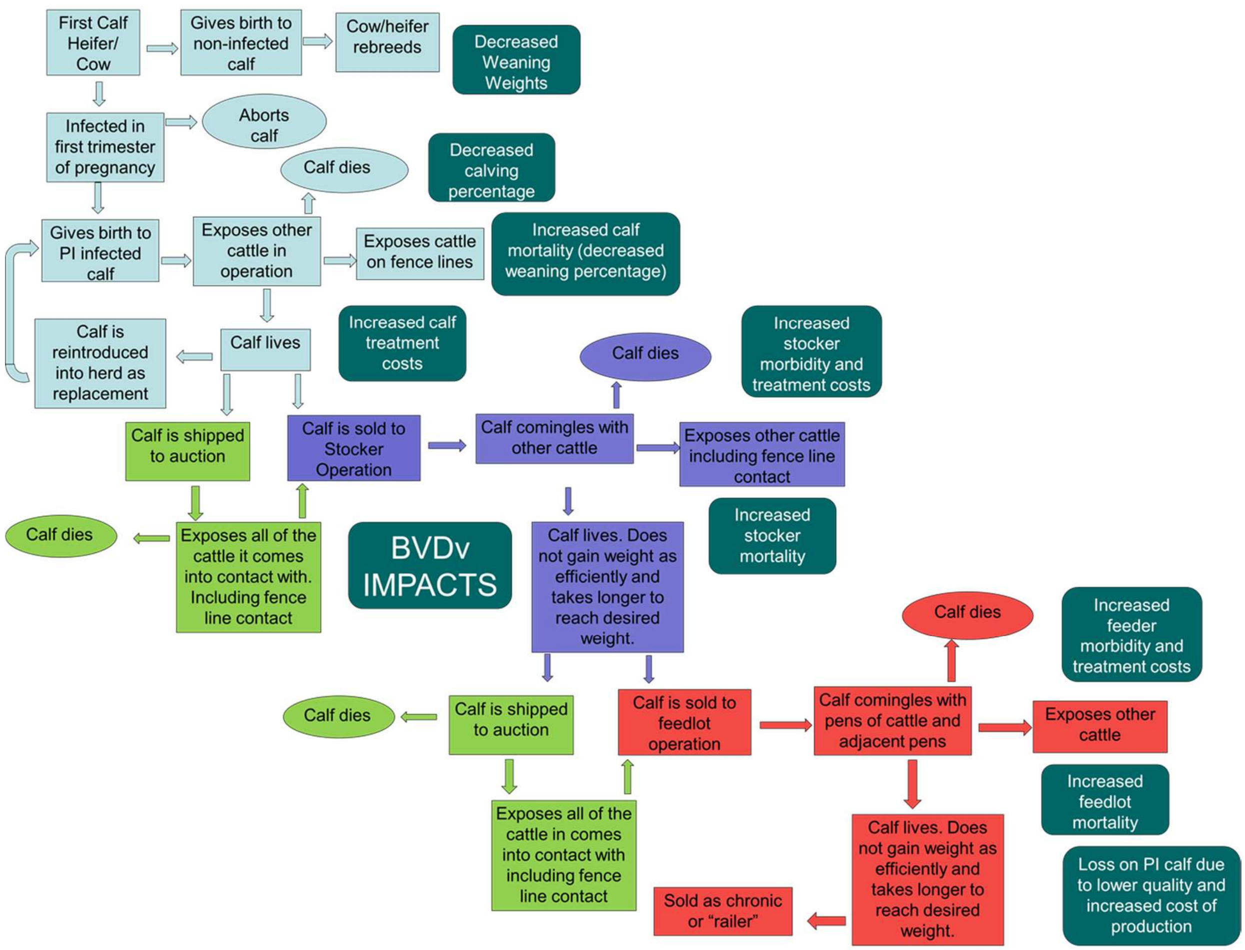
A PI calf results when the host cow or heifer is infected during the first trimester of the pregnancy. Non-infected cows will produce a healthy calf. However, infected cows will either abort the calf or give birth to a Persistently Infected (PI) calf. Increased abortion rates result in decreased calving percentage. If a cow aborts early, there is a reduced possibility of her rebreeding; however, late breeding means that the weaning weight of the calf and the average weaning weight of the herd will decrease. The cow may remain open and this results in increased herd culling. If the cow gives birth to a PI calf, the cycle of industry impacts begin. The calf exposes every other animal in the operation and compromises the immune systems of all the cattle and calves in the herd for as long as it remains in the herd. The calf will also expose any animals along the fence lines of the operation, including neighboring herds. The PI calf might die at this stage or it might survive. If it survives the calf could either be reintroduced into the herd as a replacement heifer or taken to auction, or be sold to a stocker/feedlot operation. If it is reintroduced into the operation, the PI heifer will continually give birth to PI calves and the cycle will continue in the cow-calf operation.

Once a PI calf is brought to auction, it immediately exposes all other cattle to BVDv at the auction. It also exposes all of the cattle that it came into contact with through the transportation process. Each incidence of exposure increases the chance of morbidity and mortality. The PI calf may die or be sold to a stocker operation.

Whether the PI calf came to the stocker from an auction or a direct transaction from a cow-calf producer, the cycle follows a similar path. The PI calf comingles with the pens of cattle it comes into direct contact with as well as adjacent pens. The PI calf has a high probability of mortality. If it survives, it typically has higher morbidity and it will not gain weight as efficiently which will take longer to reach a desirable weight to sell. The calf will also infect other calves which increases the chance of morbidity and mortality of exposed cattle. This increases the overall treatment costs for the operator.

If the calf survives the stocker stage it is either sold directly to a feedlot operation or taken back to auction. At the feedlot, the PI calf comingles with the pens of cattle it comes into direct contact with as well as adjacent pens. The PI calf has a high likelihood of mortality. This increases the treatment costs of sick cattle as well. BVDv exposed feeders will have significantly reduced performance with lower average daily gain and reduced feed efficiency. This will lead to a lower carcass weight as well as lower quality grading percentages (Figure 1).

Figure 1. BVDv Transmission through Beef Sectors



BVDv through the Beef Industry

Since PI cattle originate at the cow-calf level, eradication or control at this stage is the logical starting point. PI cattle are created at this level of the beef industry. This is where the commingling with non-infected animals begins and spreads throughout the beef industry. PI animals are created in the first trimester of gestation. When the calf is born, it begins shedding the disease through the herd as well as through any fence line contact on the operation. This decreases calving and weaning weight percentages. The immunosuppression that the disease causes acts as an agent in exploiting weaknesses in the immune system that then makes the animal susceptible to any disease which it comes into contact.

Though BVDv incidence is relatively low, the unique characteristics of the disease greatly amplify the exposure and impacts of the disease across the industry. For example, the 2017 U.S. calf crop was 35,808,000 with an incidence rate of 0.3 percent, implying that 10,742,400 head were PI calves (USDA NASS). Studies show that approximately 79 percent of feedlot cattle are exposed to BVDv (Larson, 2015).

The largest effect of the disease has been implicated in the environments with the largest percentage of commingling. However, control of PI is challenging at the stocker and feedlot operations. PI calves having already exposed surrounding cattle with BVDv, control is less effective. Even when isolating infected animals, cattle that come into contact with the PI animal have already been exposed and are infected by the disease. Consequently, the damage is started and on a rampage by the time the infected animals leave the cow-calf operation. Therefore the key to BVDv disease control is prevention of BVDv-PI animals from spreading BVDv by removing BVDv-PI calves before they come into contact with other cattle.

CHAPTER IV

MARKET FAILURE

Market Failure

There are multiple types of market failure. Market failure occurs in a situation in which the allocation of goods and services is not considered efficient, leading to a net social welfare loss. Market failures can be viewed as scenarios where externalities prevent the optimal allocation of goods or services. Externalities are when the gains or losses associated with the product, production or consumption of a product, differ from the private cost or benefit to the individual. These externalities can be innate to the methods of production or other conditions important to the market (Bator, 1958).

Market Failure in BVDv Control

Determining the economic impact of Bovine Viral Diarrhea in the beef industry and the economic feasibility of eradication of the disease at the cow-calf level is necessary to determine if better control of the disease is cost-effective to the beef industry as a whole. The economic impact caused by Bovine Viral Diarrhea has not been fully assessed and is costing producers thousands of dollars which could be alleviated through enhanced control (Ishmael, 2013). There is market failure when the current level of BVDv control is less than optimal for the entire industry. The largest impacts of the disease are seen at the stocker and feedlot levels where the highest percentage of comingling occurs thus translating into a negative externality due to increased mortality and morbidity along with decreased animal performance. However, the most effective method of controlling and preventing the disease remains at the cow-calf level through vaccination and eradication of PI animals (USDA APHIS, 2007).

The disease is transferred through bodily fluids, meaning any animal that is infected that encounters or sheds the virus through fluids will infect other animals. This affects the market because throughout every sector animals are exposed, and this will cost every level of the industry. However, often those costs are not fully recognized. The industry view of the disease implications is different than the views from each individual sector. The disconnect that occurs between the sectors is due to lack of recognition of the costs associated with the disease on every level. In an infected herd, a cow-calf producer will have lower calving and weaning percentages as well as increased treatment costs. Because the disease often shows up as an acute infection with obscure symptoms, the impacts are overlooked (Ridpath, 2010 'A'). Stocker and feedlot operations will have increased death loss as well as increased treatment costs and lower productivity. All of these factors increase production costs. Yet while BRD is widely recognized as a major hindrance in stocker and feedlot operations, the role of BVDv in the disease impact is not recognized. If the costs are fully recognized on every level of the beef industry, there could be a movement to close the gap in which the market failure manifests and result in an industry optimal level of BVDv control.

The incidence rates are at the highest in the cow-calf level of the industry. Conceptually, the question leading this research is identifying the optimum level of disease control. The direct costs of BVDv infection are losses from reproductive disease, from the poor performance of the PI animals, and the increased disease impacts of exposed animals. A component of this loss is directly related to the increased mortality and morbidity of PI animals. This is particularly significant in feedlots. Indirect costs such as decreased production, poor growth and increased incidence of other diseases also have large associated costs. Due to the complex nature of the BVDv infection and spread, the approaches that have been applied to model the productive and economic losses caused by BVDv infection give estimates based on calculated assumptions and most are likely to underestimate the indirect costs. These indirect costs are associated with production losses incurred by the producer and have not been fully evaluated. Nonetheless, cost estimates for both, endemic (ongoing), and epidemic (outbreak) BVDv infection exist and are used to determine what incentive is necessary to entice producers to implement vaccination programs and eradicate PI animals.

Market failure occurs because when evaluating disease control as a good, the total social costs, i.e. industry costs, are higher than the primary costs in each section. The cost of the disease is only assumed by producers to be in the morbidity and mortality costs of infected sick BVDv-PI cattle. The incidence rate in infected herds is low and the prevalence rate of herds across the United States is low, therefore most producers rely on the high probability that their herd is not infected. However, the negative externality of this disease that cause it to be a market failure is not derived from the sick cattle individually, but from their ability to shed the disease broadly and expose multiple animals in which they come into contact. A single PI calf has the capacity to shed the virus to 79 percent of the herd (USDA, 2010), meaning that 79 percent of the herd has been immunosuppressed and more susceptible to a variety of diseases that cause increased morbidity and mortality percentages. This is an indirect effect of the disease, yet it causes a direct loss to the producer and impacts profitability of the herd.

The incidence and infection rate of BVDv-PI cattle throughout the United States is relatively low. Approximately 4 percent of herds across the United States having at least one or more PI animals in their herds and the incidence rate within the herd being approximately 0.3 percent, the disease's severity is underestimated (See Chapter 2). From the 2012 Census of Agriculture report, the total number of beef farms that contained cows and heifers that calved was 727,906 (USDA NASS, 2012). The number of cattle within those farms is 29,730,518. Therefore, based on the 0.3 percent incidence rate, approximately 29,116 farms have the chance of infection with 89,191 infected animals. Therefore on average, there are approximately 3.06 infected animals per infected farm across the United States. These infected animals have the ability to commingle and come into contact with multiple locations exposing a multitude of animals, causing immunosuppression and increasing morbidity rates across the country.

CHAPTER V

METHODOLOGY AND DATA

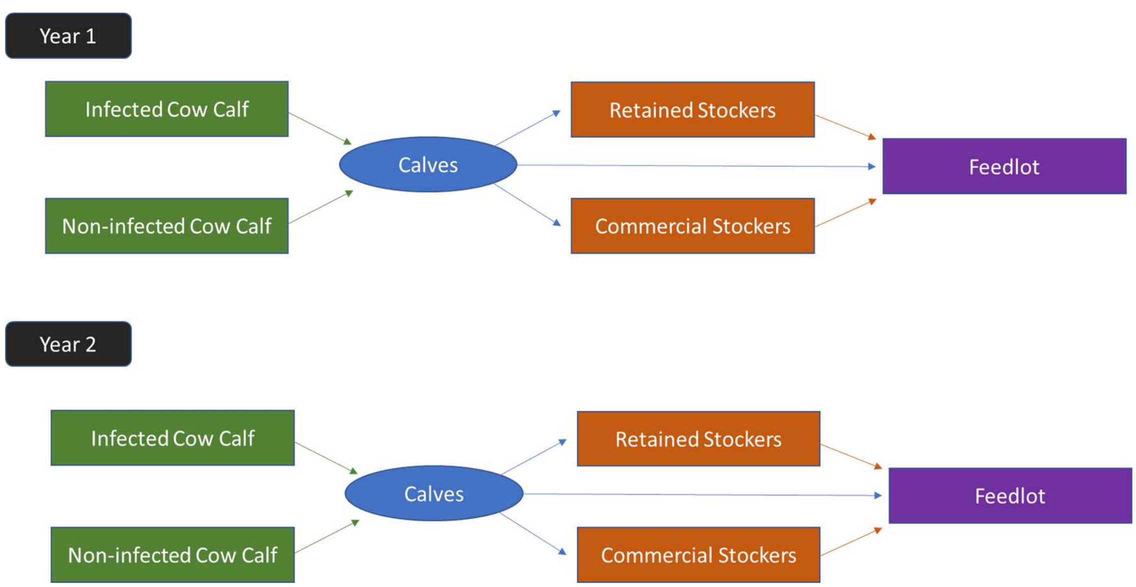
The total cost of BVDv to each sector the beef industry is not completely recognized by producers. Therefore, the benefits of a vaccination and eradication program are also not fully recognized in any sectors of the beef industry. A partial budget is an appropriate tool to outline the costs and benefits of a BVDv control program and can be implemented across involved beef industry sectors. Partial budgeting is a tool that is used to determine how a change in one part of an operation would impact an operation's returns. This is used instead of a full enterprise budget since the change would only be implemented in few areas of the operation versus across the entire operation. A partial budget only includes resources that will be changed, and it does not consider the resources in the business that are left unchanged. Only the change under consideration is evaluated for its ability to increase or decrease income in the operation. There are four components in the base budget that detail how changing or implementing a factor into an operation would change it. The main components of a partial budgeting tool are additional cost, reduced revenue, additional revenue and reduced cost. This can be accomplished at a herd and single operation basis and then applied to an aggregate level.

Simulated Herd Profile:

To determine the economic cost of BVDv at the cow-calf level, a partial budgeting tool was used to incorporate all the necessary costs and benefits of an enhanced control program. The optimal budget is a partial budget representing an operation that is infection free and has a vaccination program. The comparison of budgets illustrate multiple changes to each of the four sections in the partial budgets evaluating costs and benefits of implementing an enhanced control program for the operations.

In this case, a base budget was created for a cow-calf operation that was not infected. This operation implements a testing and a vaccination program into their protocol. Another partial budget was created for an infected cow-calf operation, a stocker operation that tests for BVDv, a non-testing stocker operation, a testing feedlot operation and a non-testing feedlot operation. A second-year budget shows that the initial cost of enhanced control lowers after the initial eradication of the infected animals. These budgets were compared to the base budget for effectiveness to determine what the monetary incentive or disincentive would have to be to encourage producers to implement an enhanced BVDv control program.

Figure 2. Budget Analysis Connection



A base herd profile was designed with assumptions to determine the cost of implementing the control program budget throughout the industry. This study simulates 1000 herds containing 100 head of animals in each herd. The average cow-calf herd size throughout the

United States is roughly 50 head of cows and 100 animals in total. This is used as a starting point. The national average calf crop percentage calculated from annual cattle inventory and calf crop numbers is about 88 percent in the last decade (USDA-NASS). Taking out the dairy sector, the beef calf crop is estimated to be 85 percent (Peel, 2018 'B'). Since tha national beef calf crop average is approximately 85 percent this results in about 42.5 calves per 50 cows on average in the simulation. Since the disease does not discriminate based on the sex of calves, the percentage of infection will be distributed across both steers and heifers. This accounts for 92.5 of the animals in the herd. The remaining 7.5 animals in the herd are assumed to be replacement heifers and bulls for the operation. The total number of animals for the simulation amounts to 100 head per herd. Therefore, the total inventory from all 1000 herds will be 100,000 head (Table 1).

Table 1. Herd Profile

Herd	**Percent of Herd**	**% of Population**	**Total**	**Total Cost**	**Per Cow Cost**
Herds			1000		
Head per Herd		100.0%	100		
Cows		50.0%	50		
Calves	85%	42.5%	42.5		
Heifers	50%	21.3%	21.25		
Steers	50%	21.3%	21.25		
Other		7.5%	7.5		
Total Head			100000		
Herd Infection Rate	4%				
Infected Herds			40		
Incidence In Herds	0.3%				
Infected Animals			300		
Infected Animals Per Herd			7.5		
Per Head Infection			0.075		
Cows/Other Prevalence	15.0%		1.125	$1,127.25	$22.55
Calves Prevalence	85.0%		6.375		
Steer Prevalence	42.5%		3.1875	$2,663.63	$53.27
Heifer Prevalence	42.5%		3.1875	$2,308.64	$46.17
Total Calf Cost					$99.45
Per Cow Total					**$121.99**

Table 1 Herd Profile

Herd	Percent of Herd	% of Population	Total	Total Cost

Herds			1000		
Head per Herd		100.0%	100		
Cows		50.0%	50		
Calves	85%	42.5%	42.5		
Heifers	50%	21.3%	21.25		
Steers	50%	21.3%	21.25		
Other		7.5%	7.5		
Total Head			100000		
Herd Infection Rate	4%				
Infected Herds			40		
Incidence In Herds	0.3%				
Infected Animals			300		
Infected Animals Per Herd			7.5		
Per Head Infection			0.075		
Cows/Other Prevalence	15.0%		1.125	$	1,127.
Calves Prevalence	85.0%		6.375		
Steer Prevalence	42.5%		3.1875	$	2,663.
Heifer Prevalence	42.5%		3.1875	$	2,308.
Total Calf Cost					

Per Cow Total

The prevalence rate among herds throughout the United States ranges from 3 percent -5 percent resulting in one or more PI animals within an infected herd (USDA APHIS, 2007). For this analysis, the average herd prevalence rate of 4 percent was utilized across the 1000 herds resulting in 40 infected herds. The incidence rate of cattle across U.S. beef herds is 0.3 percent. Meaning that 0.3 percent of all cattle in the United States are infected with BVDv (USDA APHIS, 2007). This prevalence was applied to the total number of animals in all of the herds resulting in 300 animals out of 100,000 being PI animals. Since the infected animals are only within the infected herds, they were averaged across the 40 herds that had PI animals. Each infected herd contains 7.5 PI animals on average. The prevalence rate throughout the herd will be higher in the calves versus the cows and other animals due to the fact that they are the most susceptible and are more likely to be PI animals. It was estimated that 15 percent of the prevalence is attributed to the cows and other animals while 85 percent of the prevalence is attributed to the calves (USDA APHIS, 2007). This allocation of disease prevalence is associated with the higher percentage of incidence being in calves versus mature animals. Infected animals have a high likelihood of perishing before they reach maturity. The disease affects steers and heifers equally. Therefore the calf prevalence is split equally to accommodate for the price difference between steers and heifers. Therefore, they were divided into three categories: cows/other, steers and heifers. This means that 1.125 of the PI infected animals are cows/other animals and the other 6.375 infected animals are calves which are split 50/50 between the genders (Table 1).

Costs and benefits applied in the budgets are based on data and previous literature. On average, with the eradication of infected animals and the vaccination to boost immune systems, calving percentage in a BVDv-free herd is approximately 2 percent higher than an infected herd. Weaning weight is also increased by 2 percent compared to an infected herd (USDA APHIS, 2007). Morbidity treatment is estimated to be at $0.11 on a per cow basis in a typical operation that does not have any known infection issues (NAHMS 2010). The morbidity incidence throughout cows and calves in a typical herd that does not have any BVDv incidence is estimated to be about 3 percent, while a herd that has of BVDv-PI incidence is estimated to have 15 percent morbidity (USDA APHIS, 2007). Typical treatments are done twice on mild cases of morbidity, while major cases average 3 treatments per animal. The cost of treatment is determined through the cost of vaccinations on a per animal basis for the most common problems in herd health and in particular, using antibiotics to treat sick animals (Table 2).

Table 2. Infected Herd Differences from Non-Infected

Infected Herd Costs and Benefits	**Percent Change**	**Total Percent**	**Pounds of Calf**	**Cost of Pounds**	**Per Cow Cost**
Calving percentage	-2%	83.33%	41.67		
Steers	-1%	41.67%	20.83	$348.188	$6.96
Heifers	-1%	41.67%	20.83	$301.783	$6.04
Total					$13.00
Increased Weaning Weight					
Steers	-3.0%	485.44	14.56	$24.34	$0.49
Heifers	-3.0%	461.17	13.83	$21.10	$0.42

Total	$0.91

Testing cost is based on information from Central States Testing (CST)[1]. The pooled testing which can have pools of 10 head which costs $6.50 per pool. Individual testing is $2.50 per head. If a positive result is found in a pooled test, then each animal must be tested individually to find the infected animal. To determine the pools, we assumed that mature cattle and calves were tested separately. From a management standpoint, a producer would try to minimize the number of animals in each pool so if individual testing is required in that pool then there are fewer animals to apply the second cost to. There is a maximum of 10 animals in a pool that is tested. However, if there is an infected animal in a pool, a producer will have to do an individual test on every single animal in the pool to determine the infected individual. Individual tests are $2.50 per head. Since there are 57.5 mature animals in a herd, it would require an average of 5.75 pools required to cover all of the animals. To smooth this average out, we assumed 6 pools. For calves, the average number of pools required for 42.5 animals is 4.25, once smoothed out we assumed 5 pools. If second round testing should be necessary, reducing the animals in each pool is logical so the individual costs would be applied to fewer animals in each pool. For mature animals, 57.5 animals were divided by 5 pools which is 9.58 animals a pool. This rounded to only use whole numbers amounted to 9 animals in 2 pools and 10 animals in 4 pools. For calves, there was an average of 8.5 animals in each pool. Once rounded to whole numbers amounted to 8 animals in 2 pools and 9 animals in 3 pools (Table 3).

Table 3 shows what the best and worst-case scenarios would be on the testing cost because infected cattle were determined through the pools. The individual testing would only be done on the pools of animals that tested positive instead of the entire herd. Seeing as the pools can have up to 10 animals, thus for this study the testing was assumed on the maximum incidence

[1] Oklahoma State does not endorse CST. This is for research purposes only.

rate in each category. The maximum amount of individual testing that would be required in a BVDv positive herd was $156.25 and the minimum cost was $42.50 (Table 3). The maximum total cost of testing which is pooled and then individual for an entire herd was $227.75 and the minimum cost was $114.00 (Table 3). The average cost of the minimum and maximum was $170.875 for a herd or $3.42 per cow (Table 3). It is assumed that the second round of individual testing will cost $1.00 per cow for additional labor and handling. Tagging animals to identify during testing could also be an additional expense. An important factor in implementing this control program is that the cost of testing for PI cattle is a one-time cost to the herd. Once it is determined that BVDv-PI animals are not present, the only testing that needs to occur afterward is the testing of new animals being introduced into the operation (Table 3).

Table 3. Testing for Infected Animals

Determining Pools	**Pools Required**	**Mature Animals in Pool**	**Calves in Pool**		
Mature Animal Average	5.75	9.58			
Mature Animal Actual	6				
Calves Average	4.25		8.5		
Calves Actual	5				
Pool Animal Distribution					
Pool 1		9	8		
Pool 2		9	8		
Pool 3		10	9		
Pool 4		10	9		
Pool 5		10	9		
Pool 6		10			
Total		58	43		
CST Testing per Head	**Cost**	**# in Pool**	**Individual**	**Total**	
Pooled	$6.50	10	$0.65	$65.00	
Individual	$2.50	1	$2.50		
Pooled Testing	**Cows/Other**	**Calves**			
# of Animals	57.5	42.5			
# Pools Capacity	6	5			
Incidence	1.125	6.375			
Min # of Pools	1	1			
Max # of Pools	2	5			
Min # Cattle	9	8			
Max # Cattle	20	42.5			
Cost of Individual Testing	**Test**	**Minimum**	**Per Cow**	**Maximum**	**Per Cow**
Cows/Other	$2.50	$22.50	$0.45	$50.00	$1.00
Calves	$2.50	$20.00	$0.40	$106.25	$2.13
Total		$42.50	$0.85	$156.25	$3.13
Average	$1.99				
Total Cost of Testing	**Test Cost**	**# Tested Min**	**# Tested Max**	**Cost Min**	**Cost Max**
Pooled	$6.50	11	11	$71.50	$71.50
Individual	$2.50	17	62.5	$42.50	$156.25
Total				$114.00	$227.75
Average	$170.875				
Per Cow	$3.42				

The only reoccurring cost to a cow-calf operation on a yearly basis would be a vaccination program. The vaccination cost is based on a vaccination containing IBR, BVD Types I and II, PI3 and BRSV for cows that are 50 doses a bottle with a current cost of $3.84 per head. The vaccine for calves contains IBR, BVD Types I and II, PI3, BRSV, Vibrio, 5 strains of Lepto, and is $1.27 per head or $2.54 including a second booster shot. Cows are vaccinated during pregnancy testing. Calves are vaccinated twice. Once when they are processed for branding and an additional booster shot is administered when they are weaned (Table 4).

Table 4. Vaccination

	Bovi-Shield Gold Vaccination	**Cost per Bottle**	**Doses per Bottle**	**Individual Costs**	**Booster Shot Cost**
Calves	IBR, BVD Types I and II, PI3 and BRSV	$63.39	50	$1.27	$2.54
Cows	IBR, BVD Types I and II, PI3, BRSV, Vibrio, and 5 strains of Lepto.	$191.99	50	$3.84	

To assess the value of the infected and uninfected animals, calf price data from the *Oklahoma Weighted Average Cattle Summary* was used to determine the price of 500-pound steers and 475-pound heifers. These prices were averaged over the last ten years (USDA AMS 794 KO_LS794). The value of bred cows followed Mitchell et al. (2017) and assumed culled PI cows are black, medium framed, four-year old females. The cost of eradicating the infected cows within the herd totaled $22.55 on a per cow basis (Tables 1, 5).

Table 5. Calf, Feeder and Bred Cow Values

10 Year Weighted OK Auction Prices	**Per CWT**	**Per Head**
475lb Heifers	$152.48	$724.28
500lb Steers	$167.13	$835.65
875lb Heifers	$123.01	$1,076.34
900lb Steers	$132.00	$1,188.00
Bred Cow Price Determinate		**Per Head**
Cows		$1,002.00

Morbidity and mortality incidence for the budget assumptions are based on previous incidence rates throughout feedlots. On average, death-loss across all cattle in feedlots is calculated as 1.43 percent (USDA AMS, 2007 - 2017). The Quarterly Cattle on Feed was used to determine what the percentage of heifers were in feedlots compared to steers. The percentage of death-loss that is attributed to heifers is 0.359582. The actual death-loss percentage used for a feedlot operation in this study is Kansas State University feedlot death-loss data (KSU Focus on Feedlots). The average from the past five years was 1.43 percent using a weighted average between steers and heifers in feedlots (USDA AMS, 2007 - 2017). The percentage attributed to heifers was applied to the heifer death loss and the remaining percentage was attributed to steers. This was necessary to determine the different prices attributed between the genders. On average 54 percent of feedlot total death-loss is attributed to Bovine Respiratory Disease (BRD) in which BVDv is the main immunosuppressive agent or 85 percent of the disease (USDA APHIS, 2001). For this budget, 85 percent of the 54 percent of the total death loss was assumed for the death-loss caused by BVDv. Therefore 45.9 percent of the total death-loss in an operation is attributed to BVDv (Table 6).

Table 6. Mortality

Mortality Feedlot	**Percent**	**Total**	**Total Percent Heifers**	**Heifer Death-loss**	**Steer Death-loss**
Cattle Death Total	1.43%		35.96%	0.236%	0.420%
BRD Related	54.0%				
BVDv attributed	45.9%	0.66%			
Mortality Commercial Stocker	**Percent**	**Total**	**Total Percent Heifers**	**Heifer Death-loss**	**Steer Death-loss**
Cattle Death Total	2.46%		35.96%	0.406%	0.723%
BRD Related	54.0%				
BVDv Attributed	45.9%	1.13%			
Mortality Retained Stocker	**Percent**	**Total**	**Total Percent Heifers**	**Heifer Death-loss**	**Steer Death-loss**
Cattle Death Total	1.00%		35.96%	0.165%	0.294%
BRD Related	54.0%				
BVDv Attributed	45.9%	0.46%			

In feedlot and stocker operations, the cost of treatment for morbidity is broken up into three sections. Typically, cattle in a stocker or feedlot operation are automatically vaccinated upon arrival. Cattle that arrive and appear to be sick are vaccinated and medicated upon arrival (USDA APHIS, 2001). Typically, cattle diagnosed with a respiratory disease are treated up to three times in an operation with a variety of treatment combinations. The assumption in the feedlot budget focused on respiratory diseases in feedlot operations with an incidence rate of 15 percent across all cattle in the operation (USDA APHIS, 2001). The incidence rate used for a stocker operation was approximately 16.02 percent (Peel, D.S., 2018 'B'). The most common protocol for 93 percent of operations is oral and injectable antimicrobials coupled with vaccination upon arrival to prevent any further disease which was valued at $4.00 per head. This cost included vitamin B injection, an antihistamine, and a respiratory vaccine (USDA APHIS, 2013); (USDA NASS, 2012). The cost of the various treatments is an average of the most common applications of medicine such as an injectable antimicrobial used with a corticosteroid, non-steroidal anti-inflammatory drug, an antihistamine, and a probiotic paste along with antibiotics. The medications typically include tilmicosin, florfenicol, and tetracycline (USDA APHIS 2001, 2013) the cost on a per-head, per treatment basis was approximately $8.80 on a feeder animal and $6.80 on a stocker animal. The cost difference is based on dosages assigned to different weights of cattle. This cost multiplied by the average number of treatments totaled at $26.40 per animal treated on a feedlot and $20.40 per animal in a stocker operation (Table 7, 8). Pendell et. al. (2017) found that incidence of chronic cattle valued at 0.69 percent and these are used as the assumption for chronic cattle in this study (Table 9). The price received for chronic cattle is assumed based on previous literature of $25.00 per CWT (Drovers, 2011).

Table 7. Morbidity Incidence

Morbidity Incidence Non-Infected	**Percent Attributed**	**# of Animals**
Cows/Other	3.0%	1.725
Calves	3.0%	1.275
Morbidity Incidence Infected		
Cows/Other	15.0%	8.625
Calves	15.0%	6.375

Table 8. Morbidity Treatment

Cow-Calf	**Total Cost**	**# of Doses**	**Individual Costs**	**# of Treatments per Animal**	**Total Cost Per Animal**
Non-Infected 3%					
Cows/Other Penicillin	$27.49	30	$0.92	1	$0.92
Calves Liquamycin	$23.49	25	$0.94	1	$0.94
Infected 15%					
Cows/Other Penicillin	$27.49	30	$0.92	4	$3.67
Calves Liquamycin	$23.49	25	$0.94	4	$3.76

Feeder Cattle Treatment	**Treatment Cost**	**# of Treatments**	**Total Treatment Cost Per Animal**
Vaccination	$4.00	1	$4.00
Oral Antimicrobials	$4.40	3	$13.20
Injectable Antimicrobials	$4.40	3	$13.20
Individual Treatment Per head	$8.80		
Total Treatment Cost			$26.40

Stocker Cattle Treatment	**Treatment Cost**	**# of Treatments**	**Total Treatment Cost Per Animal**
Vaccination	$3.00	1	$3.00
Oral Antimicrobials	$3.40	3	$10.20
Injectable Antimicrobials	$3.40	3	$10.20
Individual Treatment Per head	$6.80		
Total Treatment Cost			$20.40

Table 9. Chronic Cattle

Chronic Cattle	BRD Associated	BVDv Related	Total Percent	Cost per Hundredweight	Cost Per Animal
First Treatment	0.44%	85%	0.59%		
Second Treatment	0.17%				
Third Treatment	0.08%				
Total	0.69%				
Cost of Chronic				$0.25	$212.50

To determine the value of death-loss caused by the infected animals in feedlot operations, price data of the O*klahoma Weighted Average Cattle Summary* was used to determine the value of 900-pound steers and 875-pound heifers, averaged over the last ten years (USDA AMS 794 KO_LS794). The average cost of death-loss to the operations totaled $7.53 on a per head basis (Table 5). In a stocker operation, the value of death loss was determined using the price data of the *Oklahoma Weighted Average Cattle Summary* for 500-pound steers and 475-pound heifers averaged over the last ten years (USDA AMS 794 KO_LS794).

A large cost that is associated with feedlot operations is the production loss that is caused by BVDv infection. The immunosuppression that the disease inflicts on susceptible cattle is a large factor in the costs associated with production losses. On average, BVDv-PI animals shed the disease, exposing up to 79 percent of surrounding animals in an operation (Larson, 2015). Estimates of the cost of production losses for an operation varies across multiple sources. In Peck (2006) BRD accounts for approximately 70 percent of feedlot morbidity and 50 percent of feedlot mortality, negatively affecting profit**.** This study provides an economic evaluation and net return estimate associated with testing and removal of BVDv- PI calves of differing management backgrounds (low-risk preconditioned calves vs. high-risk auction market calves) (Peck, 2006).

Auction market (AM) calves gained 1.87 pounds per day and preconditioned (PC) calves gained 2.65 pounds per day for 42-day trial. Morbidity rate AM was 70 percent and PC is 6.7 percent (Vestal and Richeson, 2014). Whereas another study estimated that there was a cost of $47.00 per head of all animals that entered a feedlot (Peck, 2006). In feed yards, BVDv can cost $31-$41 per infected head (Brooks, et. al. 2011). Therefore when a 10,000 head feedlot was tested and a 0.4 percent prevalence was detected along with 72 percent of the pens being exposed to the disease, the overall observed cost per head was $47.92 across all animals (Animal Health, 2016). This resulted in total cost to the feedlot of $479,200 compared to testing costs of $35,000 (Animal Health, 2016). By exposing a general population of cattle to BVDv-PI infected animals, the performance losses vary along with the prevalence rate. The feedlot cattle in one study attributed costs of $67.49 per head across all animals due to performance losses and fatality. It was estimated that the performance losses valued at $58.83 while the remaining cost per animal is attributed to mortality (Larson et. al., 2005). On a more detailed study, the estimated costs of BVDv were approximately $93.52 per calf which include cattle that were exposed to the disease and infected cattle. The performance losses were estimated at $88.26 per animal and mortality at $5.26 per animal (Ishmael, 2013) (Table 10). When estimating production losses across all animals in a feedlot, which included infected cattle and cattle exposed to PI animals, the range was estimated to be $47.92-$58.83. The average of this range is $53.38 and this was the assumption utilized in the stocker budget. The number will be applied to all cattle that come into contact with the disease in an operation which was assumed at 79 percent of an operation.

Table 10. Performance Determination

Performance Losses	**PI**	**PI Remove d**	**Non-PI Exposed**	**Non-PI Exposed and Removed**	**Non-PI Unexposed**	**Cost of Exposure**
Gain(kg)	34	38	42	48	50	$47.92
ADG(kg)	0.55	0.59	0.68	0.73	0.74	$58.83
f/g (kg)	18.88	9.47	7.27	6.57	6.78	$53.38
COG ($/kg)	6.31	3.09	2.25	2.01	2.09	
Morbid (%)	34%	37.0%	29.2%	24.8%	29.0%	

Chronic (%)	4.6%	5.0%	3.6%	2.7%	2.8%
Dead (%)	3.6%	3.5%	2.4%	1.3%	1.7%
Average Treatment #	1.79	1.77	1.72	1.58	1.66

(Ishmael, 2013)

In the herd simulation, there are 1000 herds at the beginning, based on feedlot data used by Stehle (2017), it was determined that 30.8 percent of operations retain their stocker cattle and then sell them directly to a feedlot operation (Stehle, A.M., 2016). The cattle numbers that are used for the stocker simulation are determined by the number of calves that are born in cow-calf operations. Both in infected and non-infected herds. The assumption is that the prevalence rate is the same across retained and commercial stocker operations, yet the performance of infected retained stocker operations is like the performance of commercial operations. The incidence rate is applied to the retained stocker operations to determine how many operations would have infected cattle. Animals from infected retained stocker operations are then subtracted from total animals in retained operations and moved to commercial operations to account for the losses associated with the disease while the retained stockers are isolated and do not come into contact with the disease, therefore, the damage is significantly less.

Non-Infected Herd Partial Budget

In the non-infected cow-calf herd base budget, it was assumed that the herd tests for BVDv with zero positive test results. However, the operation still implemented a vaccination program to enhance biosecurity measures within the herd. In the additional cost portion of the budget, the operation added in testing for the herd, vaccination of the cows on a yearly basis and the vaccination of each calf crop twice. The additional cost includes the assumption that the first set of testing and vaccination will have minimal labor costs due to the processing that will already occur at the time of implementation. The reduced revenue and additional revenue portions do not have any addition to the base budget. The reduced cost portion takes into account the fact that vaccination against immunosuppression of BVDv will increase the herd's overall ability to fight infection. This, in turn, reduces the cost of morbidity across the herd. (Table 11).

Table 11. Non-Infected Cow-Calf Partial Budget (Total Head 48,000)

Negative Effects:					**Positive effects:**				
Additional Cost	Head	$/Head	Total $	$/Cow	**Additional Revenue**	Head	$/Head	Total $	$/Cow
Initial Testing									
Pooled Testing	11	$6.50	$71.50	$1.43					
Vaccination									
Cows	50	$3.84	$191.99	$3.84					
Other	7.5	$3.84	$28.80	$0.58					
Calves x 2	42.5	$2.54	$107.76	$2.16					
Total				$8.00	Total				$ -
Reduced Revenue	Head	$/Head	Total $	$/Cow	**Reduced Cost**	Head	$/Head	Total $	$/Cow
					Morbidity Treatment				
					Cows/Other	1.725	$ 0.92	$ 1.58	$0.03
					Calves	1.275	$ 0.94	$ 1.20	$0.02
Total				$ -	Total				$0.06
Total Negative Effects				**$8.00**	**Total Positive Effects**				**$0.06**
					Net Gain or Loss Per Cow				**$(7.95)**
					Aggregate				$(381,381.92)

The second year of the non-infected cow-calf operation is similar but with less testing. Testing would only be necessary if the operation introduced any new cattle into the herd. Assuming that the operation doesn't introduce any new animals indicates that the only additional cost will be the reoccurring vaccinations required each year including one shot for a bred cow during pregnancy to prevent a PI calf infection, and the two vaccinations for calves, one at branding and a booster shot at weaning to prevent an acute infecting. Since the operation is continuing a vaccination program, the morbidity costs will be lower and any still included in the reduced cost section of the budget (Table 12).

Table 12. Non-Infected Cow-Calf Partial Budget Year 2

Negative Effects:					**Positive effects:**				
Additional Cost	Head	$/Head	Total $	$/Cow	**Additional Revenue**	Head	$/Head	Total $	$/Cow
Initial Testing									
New Cattle*	0	$0.65	$ -	$ -					
Vaccination									
Cows	50	$3.84	$191.99	$3.84					
Other	7.5	$3.84	$28.80	$0.58					
Calves	42.5	$2.54	$107.76	$2.16					
Total	$100.00			$6.57	Total				$ -
Reduced Revenue	Head	$/Head	Total $	$/Cow	**Reduced Cost**	Head	$/Head	Total $	$/Cow
					Morbidity Treatment				
					Cows/Other	1.725	$0.92	$1.58	$0.03
					Calves	1.275	$0.94	$1.20	$0.02
Total				$ -	Total				$0.06
Total Negative Effects				**$6.57**	**Total Positive Effects**				**$0.06**
					Net Gain or Loss Per Cow				**$(6.52)**

*The only testing required is for any new cattle brought into the operation.

Infected Herd Partial Budget

The cost of eradicating calves on a per cow basis are estimated using the value of the calves and is multiplied by the number of infected calves and divided by the number of cows in the herd. This is determined by multiplying the percentage to the base calf crop which adds

0.8333 of a calf and is then divided equally among the genders. That is then multiplied by the values of heifers and steers respectively and is divided by the number of cows in the herd (Table 1). The calving percentages and the weaning weight percentages are assumed to be what the infection costs a herd in health. Meaning that a healthy herd has a calving percentage of 85 percent. An infected herd has a decrease in calving percentage of 2 percent. Therefore, an infected herd has a calving percentage of (Infected Herd Calving Percentage) *1.02=0.85 of 0.833. The determination is made by reducing the base healthy calving percentage by the 2 percent that an infected herd would incur. An infected herd also has a 3 percent decrease in a weaning weight compared to a non-infected herd. The weaning weight increase in steers is 3 percent which is (Steer Weaning Weight) *1.03=500 or 485.44. For heifers, (Heifer Weaning Weight) *1.03=475 or 461.12 to determine the decrease in weaning weight cost (Table 2). These numbers represent the loss in calving percentage and weaning weight in an infected herd compared to a non-infected herd produces. The adjustment in calving percentage and weaning weight percentages determine how an infected herd differs from a non-infected herd based on previous literature. By determining the calving and weaning weight percentages from the base assumptions of what a non-infected herd produces, we determine what the actual loss is for a producer with an infected herd.

In the infected cow-calf operation, the first assumption to consider is this is the first-year control program includes eradication of infected animals from the operation. This budget includes the cost of testing and vaccination in the additional cost portion of the budget. The additional cost includes the assumption that the first set of testing and vaccination will have minimal labor costs due to the processing that will already occur at the time of implementation. However, the second round of testing will incur labor costs. This is because cattle will have to be gathered and processed a second time. The labor costs are minimal due to the reduced amount of cattle that will be worked since the pools break up the cattle. The estimated labor cost is about a dollar a head for gathering and processing them for the second round of testing. The reduced revenue portion is where the cost of eradicating the infected cows/other and calves is noted. Now, this will only occur within the first year of the control program because the remaining cattle will be BVDv-PI free and additional eradication will not be necessary. In the additional revenue section, the increased calving percentage and the increased weaning weight percentages will be accounted for. The reduced cost section will take the decreased morbidity and decreased mortality costs into account (Table 8). However, the benefits that are seen from implementing a control program will continue in the following years to increase revenue and reduce cost while the reduced revenue of eradication is a one-time occurrence.

Table 13. Infected Cow-Calf Partial Budget (Total Head 2,000)

Negative Effects:					**Positive effects:**				
Additional Cost	Head	$/Head	Total $	$/Cow	**Additional Revenue**	Head	$/Head	Total $	$/Cow
Initial Testing					**Increased Calving Percentage**	3%			
Pooled Testing	11	$6.50	$71.50	$1.43	Steers	0.42	$835.65	$348.19	$6.96
					Heifers	0.42	$724.28	$301.78	$6.04
Additional Testing Avg					**Increased Weaning Weight**	3%			
Infected				$ 1.99	Steers	309.47	$1.67	$517.21	$10.34
Labor				$ 1.00	Heifers	293.99	$1.52	$448.28	$8.97
Vaccination									
Cows	50	$ 3.84	$ 191.99	$ 3.84					
Other	7.5	$ 3.84	$ 28.80	$ 0.58					
Calves x 2	42.5	$ 2.54	$ 107.76	$ 2.16					
Total				$ 10.99	Total				$ 32.31
Reduced Revenue	Head	$/Head	Total $	$/Cow	**Reduced Cost**	Head	$/Head	Total $	$/Cow
Eradication of Infected Animals					**Morbidity Treatment**				
Cows/Other	1.125	$ 1,002.00	$1,127.25	$ 22.55	Cows/Other	8.625	$3.67	$31.61	$0.63
Steers	3.1875	$ 835.65	$2,663.63	$ 53.27	Calves	6.375	$3.76	$23.96	$0.48
Heifers	3.1875	$ 724.28	$2,308.64	$ 46.17					
Total				$121.99	Total				$1.11
Total Negative Effects				**$132.98**	**Total Positive Effects**				**$ 33.42**
					Net Gain or Loss Per Cow				**$(99.56)**
					Aggregate				$(199,116.74)

*This does not include additional identification costs such as ear tags

The second year of the infected cow-calf budget will look similar to the second year budget of a non-infected operation. The testing cost would only be necessary if the operation introduced any new cattle into the herd. An assumption that the producer doesn't introduce any new animals indicates that the only additional cost will be the vaccinations required each year. This consists of one shot for a bred cow during pregnancy to prevent a PI calf infection and two vaccinations for calves, one at branding and a booster shot at weaning to prevent an acute infection. The operation went from an infected herd to a non-infected herd and the benefits of controlling the disease will continue on into the second year. The increased calving and weaning percentages will still be accounted for in the additional revenue. Since the operation is continuing a vaccination program, the morbidity costs are going to be lower so that will still be in the reduced cost section of the budget and with the decreased mortality (Table 14).

Table 14. Infected Cow-Calf Partial Budget Year 2

Negative Effects:					**Positive effects:**				
Additional Cost	Head	$/Head	Total $	$/Cow	**Additional Revenue**	Head	$/Head	Total $	$/Cow
Initial Testing					**Increased Calving Percentage**	3%			
New Cattle*	0	$0.65	$ -		Steers	0.42	$835.65	$348.19	$6.96
					Heifers	0.42	$724.28	$ 301.78	$6.04
Vaccination									
Cows	50	$3.84	$191.99	$3.84	**Increased Weaning Weight**	3%			
Other	7.5	$3.84	$28.80	$0.58	Steers	309.47	$1.67	$517.21	$10.34
Calves x 2	42.5	$2.54	$107.76	$2.16	Heifers	293.99	$1.52	$448.28	$8.97
Total				$6.57	Total				$ 32.31
Reduced Revenue	Head	$/Head	Total $	$/Cow	**Reduced Cost**	Head	$/Head	Total $	$/Cow
					Morbidity Treatment				
					Cows/Other	8.625	$3.67	$31.61	$0.63
					Calves	6.375	$3.76	$23.96	$0.48
Total				$ -	Total				$1.11
Total Negative Effects				**$6.57**	**Total Positive Effects**				**$ 33.42**
					Net Gain or Loss Per Cow				**$26.85**

*The only testing required is for any new cattle brought into the operation.

The implementation of the enhanced control program that assumed in these budgets will start in the fall during pregnancy testing of cows and weaning of calves. Meaning that the spring calves should have a higher weaning weight because they will not be surrounded by infected animals. The calving percentage would also increase due to the reduced exposure to the disease. This continues into the next year because the herd will reach the status that a non-infected herd would have which increases profits.

Commercial Stocker Partial Budget

It is estimated that 69.2 percent of cattle that are brought into a commercial stocker operation before they are transported to a feedlot operation. In this simulation, the infected cattle that typically would have been in the retained stocker operations were subtracted from the retained and added to the commercial operations because the performance of the cattle is amounts to performance expected in a commercial operation compared to a retained stocker operation. As a result, the percentage of cattle in this simulation that is calculated to be from a commercial stocker operation is 69.3 percent (Table 12). The cattle that are brought into a stocker operation are vaccinated upon arrival. The vaccination cost has multiple components and was valued at $3.00 per head in the operation. Testing is not incorporated into this budget due to the testing that is incorporated in the cow-calf operations. Additional testing in a feedlot operation would be moot assuming that all BVDv infected cattle are eradicated at the cow-calf level. The additional cost will still require vaccinations on a per head basis throughout the operation to continue management of the disease. The additional revenue accounts for the decrease in death-loss that is related to respiratory disease. This is accounted for using stocker values in the Oklahoma weighted average auction data. The estimated size of the commercial stocker operation in this current budget is 29,439 head of cattle, a total death-loss of 1.13 percent of the population and is distributed using a weighted average between steers and heifers (Peel, D.S., 2018 'A'). The reduced cost segment accounts for the reduced morbidity within the operation that is related to respiratory disease and is determined on a per head cost basis (Peel, D.S., 2018 'A'). The performance losses are based on previous literature on a per head basis over all animals. This estimation included infected animal losses along with the losses attributed to animals that were exposed to the disease on a per head basis (Table 15).

Table 15. Commercial Stocker Partial Budget (Total Head 29,439)

Negative Effects:					**Positive effects:**				
Additional Cost	Head	$/Head	Total $	$/Total Head	**Additional Revenue**	Head	$/Head	Total $	$/Total Head
Vaccination					Death-Loss	1.129%			
Cattle	1	$3.00	$ 3.00	$ 3.00	Steers	212.88	$835.65	$177,894.50	$6.04
					Heifers	119.53	$724.28	$86,572.31	$2.94
Total				$ 3.00	Total				$8.98
Reduced Revenue	Head	$/Head	Total $	$/Total Head	**Reduced Cost**	Head	$/Head	Total $	$/Total Head
					Morbidity Treatment	16.02%			
					Sick Cattle	4716.17	$20.40	$96,209.83	$3.27
					Performance Losses	79%			
						23257.01	$25.00	$581,425.23	$19.75
Total				$ -	Total				$23.02
Total Negative Effects				**$ 3.00**	**Total Positive Effects**				**$32.00**
					Net Gain or Loss				**$29.00**
					Aggregate				$853,784.11

Retained Stocker Partial Budget

Some cattle are retained from non-infected cow-calf operations and kept on the operation as stockers before being sold directly to an auction or a feedlot which bypasses a commercial stocker operation. This differs from a commercial stocker operation because the death loss and morbidity incidence decrease since the cattle are not transported and comingled. These cattle have minimal exposure, therefore, they have minimal impacts inflicted by the disease. It is estimated that 30.8 percent of cattle that remain in a non-infected retained stocker operation before being sold to a feedlot. In this simulation, a total of 13,027 cattle remain in a retained operation. The incidence rate was applied to the stocker operations to determine that 1.02 retained stocker operations have BVDv infected cattle (Table 16). Those operations were added to the commercial stocker operations because the performance and morbidity would be on par with those operations compared to a non-infected retained operation. Therefore, in this simulation, the percentage of total cattle that are in a retained operation was reduced to 30.68 percent (Table 17).

Table 16. Cattle throughout Simulation

Operation	Herds	Cows	Calving Percentage	Calves	
Initial	1000				
Infected Calves	40	2000	83.33%	1666.67	
Non-Infected Calves	960	48000	85.00%	40800	
Total				42466.67	
Operation	**Percentage**	**Herds**	**Prevalence**	**# of Operations**	
Retained Stocker	30.80%	308	0.40%	1.232	
Commercial Stocker	69.20%	692	0.40%	2.768	
Operation	**Herds**	**Percentage Distribution**	**Animals in Operation**	**Death-loss**	**Survived to Feedlot**
Retained Stocker	306.77	30.68%	13027.41	1.00%	12897.14
Commercial Stocker	693.23	69.32%	29439.25	2.46%	28715.05
Total					41612.19

Table 17. Retained Stocker Partial Budget (Total Head 13,027)

Negative Effects:					**Positive effects:**				
Additional Cost	Head	$/Head	Total $	$/Total Head	**Additional Revenue**	Head	$/Head	Total $	$/Total Head
Vaccination					Death-Loss	0.46%	59.80		
Any additional Cattle	0	$3.00	$ -	$ -	Steers	38.29	$835.65	$32,000.65	$2.46
					Heifers	21.50	$724.28	$15,573.11	$1.20
Total				$ -	Total				$3.65
Reduced Revenue	Head	$/Head	Total $	$/Total Head	**Reduced Cost**	Head	$/Head	Total $	$/Total Head
					Morbidity Treatment	1.00%			
					Sick Cattle	130.27	$20.40	$ 2,657.59	$0.20
					Performance Losses	1%			
						130.27	$ 25.00	$ 3,256.85	$0.25
Total				$ -	Total				$0.45
Total Negative Effects				**$ -**	**Total Positive Effects**				**$4.11**
					Net Gain or Loss				**$4.11**
					Aggregate				$ 53,488.21

Feedlot Partial Budget

The cattle that are brought into a feedlot operation were vaccinated upon arrival. The vaccination cost was valued at $4.00 per head in the operation. Testing was not incorporated into this budget due to the testing that was incorporated in the cow-calf operations. Addition testing in a feedlot operation would be moot assuming that all BVDv infected cattle were eradicated at the cow-calf level. The additional cost still required vaccinations on a per head basis throughout the operation to maintain adequate management of the disease. The additional revenue accounts for the decrease in death-loss that is related to respiratory disease. These were valued for using Oklahoma weighted average auction data. Feedlots are assumed to have a total death-loss of 1.43 percent of the population and was distributed using a weighted average between steers and heifers. The reduced cost segment accounted for the reduced morbidity within the operation that was related to respiratory disease and was determined on a per head cost basis. The performance losses were estimated through the previous literature on a per head basis over all animals. This estimation included infected animal losses along with the losses attributed to animals that were exposed to the disease in a cost per head basis (Table 18).

Table 18. Feedlot Partial Budget (Total Head 41,612)

Negative Effects:					**Positive effects:**				
Additional Cost	Head	$/Head	Total $	$/Total Head	**Additional Revenue**	Head	$/Head	Total $	$/Total Head
Vaccination					**Death-Loss**	0.66%	273.129911		
Cattle	1	$4.00	$4.00	$4.00	Steers	174.92	$1,188.00	$207,801.77	$4.99
					Heifers	98.21	$1,076.34	$105,709.90	$ 2.54
					Chronic	0.587%			
					Cattle	244.06	$212.50	$51,861.79	$1.25
Total				$4.00	Total				$8.78
Reduced Revenue	Head	$/Head	Total $	$/Total Head	**Reduced Cost**	Head	$/Head	Total $	$/Total Head
					Morbidity Treatment	15%			
					Sick Cattle	6241.83	$26.40	$164,784.26	$3.96
					Performance Losses	79%			
						32873.63	$53.38	$1,754,629.88	$42.17
Total				$ -	Total				$ 46.13
Total Negative Effects				**$4.00**	**Total Positive Effects**				**$ 54.91**
					Net Gain or Loss				**$ 50.91**
					Aggregate				$ 2,118,338.85
					Per Animal				$ 21.18

CHAPTER VI

RESULTS AND CONCLUSIONS

Results

In the previous section, the budgets and their components were discussed and evaluated to assess how the different components changed the value of the enhanced control program implementation.

Non-infected Cow-Calf Operation Year 1

Given that 96 percent of cow-calf operations are uninfected, this is the most common outcome for cow-calf producer and this budget represents what happened for these producers assuming they implemented an enhanced control program into their operation. The net gain of introducing an enhanced BVDv control program resulted in a net loss for the non-infected cow-calf producer of $7.64 per cow. This cost was primarily associated with the initial cost of testing along with the vaccination program (Table 11).

Non-infected Cow-Calf Operation Year 2

The net loss in the second year for the non-infected cow-calf producer was $6.46 per cow. Year 2 does not include testing costs for the operation. Vaccinations were a reoccurring cost for operations to maintain the optimum enhanced control. This budget showed the amount that producers would require as an incentive to maintain control of the disease (Table 12).

Infected Cow-Calf Year 1

Infected cow-calf herds had BVDv incidence and were operating below optimal production capacity relative to a non-infected operations. Multiple impacts result from the disease such as calving and weaning weight reductions as well as overall productivity. The calving percentage increase amounted to approximately $13.00 per cow because an infected herd had about 3 percent less of a calving percentage compared to a non-infected herd (Table 2). There was also an impact on the weaning weight percentage of about 3 percent for both heifers and steers (Table 2). In this budget, the cost of eradicating infected animals is incorporated into the reduced revenue section of the operation. The cost per cow of eradicating infected mature animals was $22.55 (Table 1). The cost of eradicating infected steers and heifer on a per cow basis was $99.45 (Table 1). The testing costs were higher compared to a non-infected herd because of the second round of testing required which also incurred additional labor costs to gather and process the cattle. However, the increased calving and weaning percentages help alleviate the added costs of testing and eradicating the disease along with vaccination. The first year in this budget analysis found that the cost of implementing a control program resulted in a net loss in the first year of $96.21 per cow for an infected cow-calf operation (Table 13).

Infected Cow-Calf Year 2

The second year of the infected cow-calf operation was similar to the second year of the non-infected cow-calf operation. The testing costs are only required for new cattle and the infected animals had already been disposed of. The difference was they will still reap benefits from eradicating the disease in the second year. After year two, they will stay at the same level as the non-infected operation. The benefits derived from the increased productivity of the herd. The net gain for the infected cow-calf producer in the second year of the control program was $27.96 per cow (Table 14).

Commercial Stocker

The commercial stocker operation is where the first round of major comingling occurs in the beef industry. Therefore, cattle that are BVDv-PI positive sheds the disease to all animals it encountered. In a BVDv positive environment, feedlot data show that 79 percent of all animals are exposed to BVDv. BVDv exposure is at least as high in stocker operations or perhaps higher since animals tend to be commingled into larger grazing groups. The production, morbidity and mortality losses caused by BVDv show how detrimental the impacts are in this sector. In a commercial feedlot operation, 1.129 percent of all death loss was attributed to BVDv (Table 12) and morbidity was at 16.02 percent (Table 17). The net gain that a commercial stocker operation observed from this enhanced control program was $48.89 per head (Table 15).

Retained Stocker

Since infected cattle were removed at the cow-calf level, the impacts on non-infected retained calves is small for retained stocker operations. The death-loss and morbidity still had a small presence assuming acute infections were still possible through fence-line contact. The net gain for retained stocker operations was $4.39 per head (Table 17).

Feedlot

The largest impact of BVDv occurred at the feedlot level. This was where all cattle commingled and the most likely scenario for the disease to manifest. Morbidity, mortality and productivity were all accounted for to determine the gain realized by feedlots from controlling the disease. The loss of productivity was the largest impact, which accounted for 84 percent of feedlot losses due to BVDv. The net gain for a feedlot operation was $50.28 per head (Table 18).

Aggregate Market Impacts

Even though the non-infected herds were more likely, and the cost of enhanced control seemed to be a net loss, the outcome, in the end, shows that enhanced control would ultimately be a cost-effective endeavor across the entire industry. The effect of the disease was most severe at the stocker and feedlot levels of the industry, yet the most effective control occurred at the cow-calf level. In this simulation, a cow produces 414.375-pounds of calf when the weight was averaged between steers and heifers and then adjusted by the calving percentage. This averaged out to 4.14 hundredweight (Table 19). The cost of enhanced control in the first year for non-infected cow-calf operations is $7.64 per cow. After dividing the cost of the pounds per cow produced, the resulting premium that would be needed to cover the cost of enhanced control is $1.84 per hundredweight (Table 19). This would only be required in the first year. The cost of control in the second year was $6.46, therefore, the premium required would be $1.56. For an infected cow-calf operation, the valuation of implementing an enhanced control program into their operations had a negative value in the first year and then a positive value the next year. Assuming a discount rate of 4 percent over ten years, the net present value of the implementation was $107.39 per cow in the operation (Table 20).

Table 19. Average Pounds of Calf Produced Per Cow

Calving %	Avg lbs of Calf	Avg lbs Per Cow	Pounds per CWT	Cost Per Cow Non-Infected	Premium Per CWT
85%	487.5	414.375	4.14375	$(7.95)	$(1.92)
				$(6.52)	$(1.57)

Table 20. Net Present Value

Year		Value	Rate of Return	NPV
1	$	(99.56)	0.04	$96.23
2	$	26.85		
3	$	26.85		
4	$	26.85		
5	$	26.85		
6	$	26.85		
7	$	26.85		
8	$	26.85		
9	$	26.85		
10	$	26.85		

By evaluating the numbers on an individual basis for each sector and for individual head, the impacts are on a smaller scale. By applying the numbers to the full capacity of a simulation, the impacts are visible. For 96 percent of the population, the cost of implementing this control program is $366,801.68 (Table 11). For the 4 percent of the population, the cost of implementing this program is $192,422.45 (Table 12). However, the gain for commercial stocker operations is $779,299.83, for retained stockers it is $53,488.21, and for feedlots it is $2,092,102.88 (Tables 15, 17, 18).

By evaluating the costs in both the non-infected and infected cow-calf operations, the total cost would be $559,224.12 or $5.76 per every animal in the simulation (Table 21). The total benefit to the commercial stockers, retained stockers and feedlots is $2,999,375.21 or $29.99 per every animal in the simulation (Table 21). The total net benefit of implementing the enhanced control in this simulation is $2,423,766.99 across all sectors or $24.24 per animal in the simulation (Table 21).

Table 21. Aggregate BVDv Impacts from Simulation

Operation	Cost	Benefit
Non-Infected Cow-Calf	$(381,381.92)	
Infected Cow-Calf	$(199,116.74)	
Retained Stocker		$53,488.21
Commercial Stocker		$853,784.11
Feedlot		$2,118,338.85

Total	$(580,498.67)	$3,025,611.17
Cost per every animal	$(5.80)	
Benefit per every animal		$30.26
Net total benefit		$2,445,112.51
Net benefit per animal		$24.45

Conclusions and Industry Implications

The results of this analysis confirm that the current level of BVDv control in the beef industry is less than optimal. The unequal distribution of costs and benefits across beef production sectors, combined with under recognized BVDv impacts at all levels is causing a market failure that results in a sub-optimal level of BVDv control. The budget analysis suggests that at the aggregate level, there is ample value in controlling the disease at the stocker and feedlot levels which could compensate cow-calf producers for implementation of a control program. This leads to the question of how the benefits can be redistributed to provide additional incentives for enhanced BVDv control.

The cattle industry consists of complex production processes across all sectors. The implementation of the control program must start at the cow-calf operation to control the production of PI cattle. However, demand for reduced BVDv-PI animals will have to be at the stocker and feedlot operations. If the demand for BVDv free cattle starts with feedlots and stockers, then cow-calf producers will follow suit to meet demand. Even though change can be hard to adapt to, if operations are not paying for infected cattle, they producers will adapt and produce a desired product.

Once control is implemented in the cow-calf sector, the infected animals will be eradicated and that will be the last year of infected animals in the cow-calf sector. However, the infected cattle will still be moving throughout stocker/backgrounding and feedlot operations. The infected cattle will remain within those operations until the non-infected batch of animals from the cow-calf operations cycle through. This is estimated to occur 2 years after the initial implementation of the enhanced control program. The budgets and profile of implementing the control program are based on a breeding year cycle. The testing occurs in June when branding is taking place just before the bulls are placed back into the herd for the new cycle. Infected cows and calves are identified within the herd and disposed of. The operation will then see the benefits of the disease control within the next year. Calving percentage will increase because all cows are vaccinated against acute infections and the presence of PI cattle will be non-existent. Weaning weights will increase in the next year as well because of the lack of exposure and immunosuppression. If a producer would wait until October or weaning, the budgets would incorporate an additional year until the benefits of eradicating the disease were visible. The cycle would be pushed back and the effects of the disease would have already affected the calf crop on the ground and the cattle that are pregnant with the upcoming calf crop.

The mental approach that should be used to this control situation is similar to a financial investment situation. The first year will require sacrifice in order to obtain the maximum benefit of the program. This sacrifice constitutes the eradication of the infected animals from the herd. This will cause a loss for the producer in the first year because the infected cattle should be eliminated to deter any further spread of infection. The second year will be when the benefits are recognized. Overall herd health and profit will increase which benefits the producer throughout the following years. Over time, the enhanced control of the disease will reap more benefits than the initial incurred costs.

Market failure is extensive throughout the sectors in this disease control issue. The cost of implementation and control resides predominately on the cow-calf sector in the beef industry. However, the stocker and feedlot operations would benefit extensively. This disconnect occurs because the majority of cow-calf producers do not receive any benefits for disease control since 96 percent of the operations are not infected. Only infected operations see benefits from implementing a control program. The main issue is that a PI animal sheds the disease and causes mass performance loss across an operation where there is extensive commingling. This is why there would be such a large benefit for feedlots and stockers to control the disease by reducing those losses from occurring. Once an optimal solution is reached in the market, the impacts should be neutralized and the cost of controlling the disease will be reduced. The majority of the cost to control the disease will occur within the first year. Beyond that, the cost of control will be minimal with the same benefits. However, the largest issue will be producing a benefit that will entice cow-calf producers to implement the enhanced control program.

Limitations on Work

The greatest limitation of this research is even though veterinary knowledge about the disease itself is extensive, the economic information on the disease was variable, inconsistent and far-reaching. The biggest issue was determining where the initial economic assumptions should stem from because the literature was inconsistent. Therefore, a large part of this simulation is based on assumptions that were determined using the available resources. The assumptions might seem high and extensive in multiple parts such as the performance losses. However, the cost of implementing the control program would still be plausible even if the benefits of control were cut in half or a third of the original assumption. The second largest issue with determining the economic impact of BVDv is the fact that BRD and BVDv are so closely aligned and there is not an extensive amount of specific definition of the two diseases. BRD is amplified through BVDv immunosuppression, however, this is not necessarily specifically quantified. This makes determining the actual economic value difficult. Most of the previous literature focuses on a particular section or sector of the beef industry. This analysis synthesized the expanse of the industry to determine what impacts occurred on every level and how the market failure was actually applicable to the problem. This revealed the difficulty of evaluating three diverse and specific sectors while trying to evaluate the implications that followed a disease through all sectors. The third issue that limited the research was the number of assumptions based on previous literature. There is not an all-inclusive literature source that depicts the disease impacts and issues through all three of the sectors. Assumptions were pulled and made through multiple sources that had a variety of ranges incorporating the disease costs and impacts. The final limiting factor of this research is that the disease itself is constantly changing and evolving along with research. The costs of testing and vaccination are currently up to date, however, this will not remain so for long. The research and understanding that incorporates the disease is constantly changing because of its complexity and severity of its impacts. That makes this an ever-changing project that is just as fluid as the disease.

Suggestions for Further Work

This research can be expanded in multiple ways. First, a full breakdown of the benefits and costs associated with BRD, BVDv and BVDv-PI and how much they differ would be useful. The second topic is how much the disease would be costing the industry if uncontrolled, including the implications of losses for the next ten years. The other interesting topic is a full economic valuation of the production losses associated with BVDv alone. The losses are not excessively detailed and the assumptions of the losses are only based off of a few studies. Another implication of the enhanced control implementation is the effect that it would have on the beef cattle price market. If the disease was controlled at the cow-calf level, it would be assumed that the death-loss, morbidity and production losses would all be alleviated from it. This would cause a shift in the price structure of the beef industry. Supply would increase by a substantial amount without a shift in demand. This would shift the market structure and the price would change to reflect the shift in supply. The increased supply causes a surplus of beef that would be available to consumers. There are multiple possibilities of continuing this research.

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Biographical:

Education:

Completed the requirements for the Master of Science/Arts in Agriculture Economics at Oklahoma State University, Stillwater, Oklahoma in May, 2018.

Completed the requirements for the Bachelor of Science in Agriculture Economics/Agriculture Business at New Mexico State University, Las Cruces, New Mexico in 2016.

Experience:

Professional Memberships: